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Geology and ore deposits of the Clinton mining district Missoula County Montana

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GEOLOGY AND ORE DEPOSITS

OF THE CLINTON MINING DISTRICT

MISSOULA COUNTY, MONTANA

by

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A B S T R A C T

Approximately four square miles and all accessible underground workings in the Clinton mining district of western Montana were mapped and studied in detail. Discovered in 1878, the district has produced copper, silver, lead and gold, having a total value of approximately $100,000. The bulk of this production has come from the Hidden Treasure and Cape Nome mines.

The most important rock unit in the area is a late Cretaceous or early Tertiary granodiorite stock which was intruded transverse to northwest trending folds of the Laramide orogeny. The stock cuts late Precambrian Beltian quartzites of the Missoula group and a diabase sill which they contain. Post-stock rhyodacite porphyry dikes were intruded along tensional fractures that cut all rocks in the district. Later tensional fractures provided openings along which ore minerals were deposited.

The ore deposits occur both in the granodiorite, as discontinuous fissure fillings in veins that trend north-south and dip west, and in the adjacent quartzites, as lens-shaped replacement bodies in northeasterly trending shear zones that dip east. In order of their paragenetic sequence, the ores consist mainly of chalcopyrite, bornite,

enargite, and chalcocite in the granodiorite and chalcopyrite, tetrahedrite and galena in the quartzites.

In the quartzites of the Hidden Treasure mine, significant mineralization occurs most often where west-dipping splits diverge from the predominantly east-dipping veins. The structure of the ore bodies in the 4001 raise of the Hidden Treasure mine is complicated by four stages of movement, each of which cut and displaced previous mineralized structures.

Surface and underground vein exposures indicate that the best economic possibilities may be found in zones of supergene sulfide enrichment like the one that accounted for most of the past production in the Hidden Treasure mine.

I N T R O D U C T I O N

LOCATION AND ACCESSIBILITY

The Clinton mining district (Figure 1) lies within the western part of the Garnet Range, twenty miles east of Missoula and two miles northeast of Clinton, Montana. It is situated in Sections 13 and 24, Township 12 North, Range 17 West, and Sections 17, 18, 19 and 20, Township 12 North, Range 16 West, Principal Meridian Montana. U. S. Highway No. 10 and the main lines of the Northern Pacific and the Chicago, Milwaukee and St. Paul railroads pass through Clinton. A county-maintained road affords access to most of the district except in the late winter and early spring months.

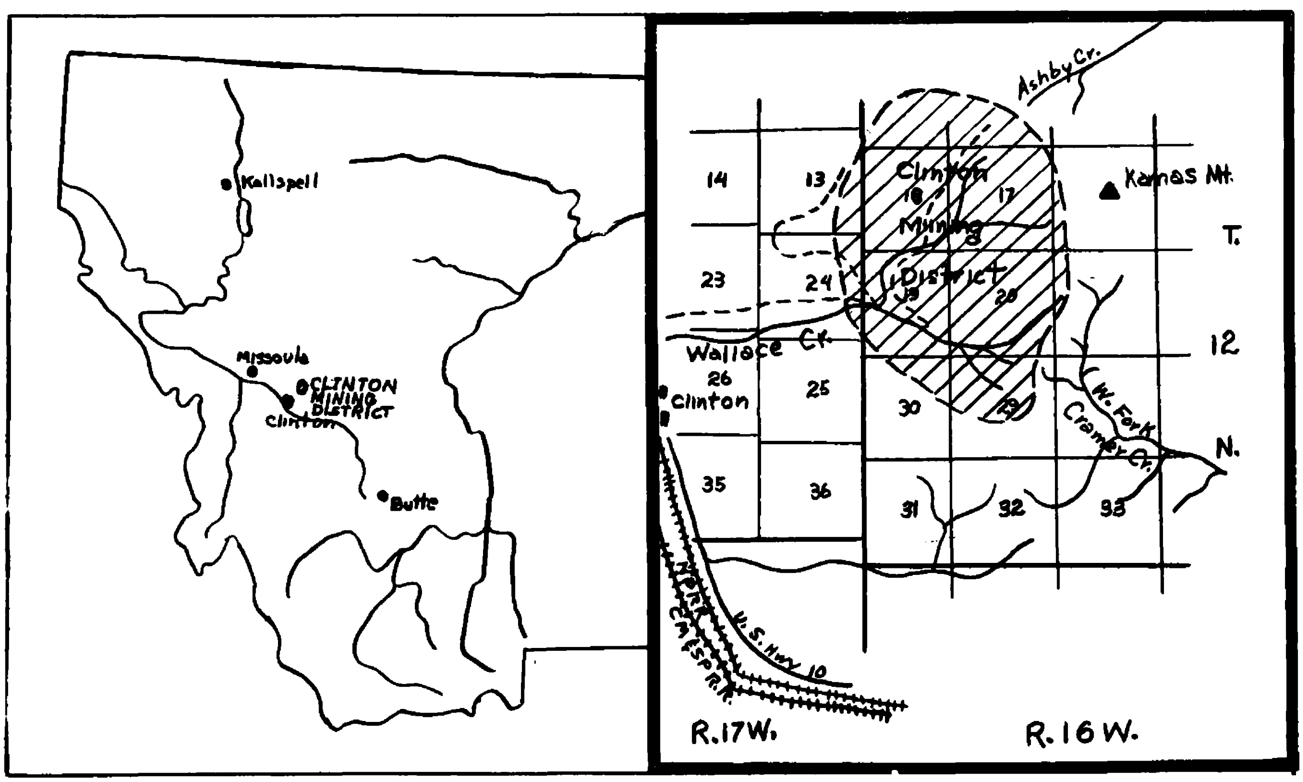


Figure 1 - Index map of Montana, showing location of the Clinton mining district

PURPOSE OF THE INVESTIGATION

The purpose of this study was (1) to obtain a detailed picture of the surface and underground geology of the Clinton mining district, (2) to work out the mineralogy and paragenetic relationships of the ore minerals, and (3) to determine the factors controlling ore deposition. It is hoped that this information can be used in the development of paying mines in the district.

PREVIOUS WORK

There is little published literature dealing with the geology of the Clinton district. Most of the reports are of a reconnaissance nature.

Rowe (1910) briefly described the general geology and the more important properties at a time when there was a great amount of activity and interest. His work is of particular value because most of the workings he visited are inaccessible at the present time. However, in most instances he presented a somewhat more optimistic description of the economic potential than was found during this investigation.

Pardee's reconnaissance of the western part of the Garnet Range (1918) gives a description of the geology and more important properties, but it is very general.

The geology of the upper levels of the Hidden Treasure mine was described by Piquette (1941) during an exploratory program on the 4260 foot level. He also described the surrounding geology, but added little to what had already been said by Rowe and Pardee.

In 1943, 1944 and 1945 the United States Bureau of Mines undertook a program of sampling and diamond drilling. A number of properties were examined and extensive sampling was done on the Queen Mary and the Hidden Treasure claims. The results of this work were quite disappointing, however, and the project was discontinued (Brinton, 1946).

Sahinen (1957) described several of the properties in the district; his report was based on a survey of previous literature and brief visits to some of the individual properties.

Reports by Brynie (1959), Matson and Leischner (1959) and Toler and Schryver (1958) are on file with the Department of Geology, Montana State University. They were submitted for a course in geologic problems, and cover localized problems in mapping and sampling.

PRESENT STUDY

The field work for this study began in June 1958 and was conducted, as time permitted, through July 1959, while the writer was employed as a geologist for Hera Exploration Company of Clinton, Montana. Approximately 30 days were spent on field work directly related to the investigation.

The underground geologic mapping necessitated a transit survey of all the accessible mine workings and construction of base maps upon which the geologic data of selected portions of the mine were plotted. A scale of one inch equals 20 feet was chosen (Plates 1, 2, 3 and 4) in order to show as much geologic detail as possible on a relatively small map.

Surface geological data covering approximately four square miles were plotted directly on vertical aerial photographs having a scale of 1:17,500. (Commodity Stabilization Service photographs dated August 11, 1955). The final surface map (Plate 6) was prepared by transferring the geologic data to a planimetric base map constructed from the aerial photos by means of a K. E. K. stereoscopic plotter; this transfer removed distortion due to differences in elevation and enlarged the scale to approximately one inch equals 1300 feet. Land net control was established by matching the planimetry of the base map with that of an aerial "strip tracing" on file at the Regional Offices of the U. S. Forest Service, Missoula, Montana.

Laboratory work involved making petrographic descriptions, identifying minerals in ore samples, and studying their textural and paragenetic relationships. A total of 43 polished sections and 15 thin sections were prepared and studied. Photomicrographs were made of certain polished sections which best show mineral relationships.

ACKNOWLEDGEMENTS

Many people have contributed to the completion of this study. Appreciation is extended the officers and stockholders of Hera Exploration Company who have generously given their permission to use company information for this report. The writer gives special thanks to B. L. Hicks for his assistance in constructing the base maps, and to Gary G. Morrison for his help with the field work. Professors R. M. Weidman, A. J. Silverman, R. A. Brodersen and J. W. Hower of the Geology Department of Montana State University offered valuable assistance and constructive criticism which was invaluable in the preparation of this thesis. E. M. Schell gave freely of his time to assist on mineralogical problems. A special acknowledgement is due the writer's wife, Bonnie, for her typing and suggestions.

HISTORY AND PRODUCTION

The Clinton mining district was discovered in 1878, when the first locations were recorded by J. D. Richards, James House and S. F. Keim. There was little activity, however, until about 1905, when exploratory work was initiated in the Cape Nome mine. This seemed to draw interest to the entire district because between 1905 and 1912 a number of properties were being actively explored. Apparently, low metal prices and discouraging mineral showings resulted in virtual abandonment of the district for many years. During the flurry of activity between 1905 and 1912, more than a mile of underground workings were driven on the Cape Nome claim. This included sinking 500 feet of vertical shaft and driving nearly 5500 feet of drifts and crosscuts on five levels. Considerable workings were also driven on the Hidden Treasure claim.

From 1912 to the present time, sporadic, small-scale production and exploration have been carried on in the Hidden Treasure and Cape Nome mines. Some prospecting has been done in other parts of the district, but no other production is known.

In 1956 Hera Exploration Company of Clinton, Montana, leased the Hidden Treasure, Cape Nome and several other claims in the district. Since that time the company has re-opened the 100-foot level of the Cape

Nome mine and temporarily dewatered the shaft to the 300-foot level for examination. During the summer of 1958 small scale production was obtained from the 4000-foot level of the Hidden Treasure mine.

In 1957 Clinton Mining and Milling Company of Clinton, Montana, completed installation of a 50-ton per day bulk flotation plant on Wallace Creek. This mill was constructed to beneficiate ore produced from Hera Exploration Company operations, as well as from other nearby properties. During three years of intermittent operation (to December 1960), the mill produced four carloads of copper concentrates, which were shipped to the smelter at Anaconda, Montana.

Early in 1959 Hera Exploration Company undertook a program to extend the 4000-foot level (No. 2 tunnel) of the Hidden Treasure mine some 2600 feet to a point under the Cape Nome workings. In December 1960 this half-completed venture apparently was abandoned and attempts were being made to develop sufficient ore in the Hidden Treasure mine to operate the Clinton Mining and Milling Company mill on Wallace Creek.

According to Pardee (1918) the total production of the district through 1917 did not exceed $25,000.00. Table 1 shows the production of the Clinton district from 1934 to 1960. No information is available for the period 1918 - 1934.

Table 1

Year	Ore tons	Gold oz.	Silver oz.	Copper lb.	Lead lb.	Total Value
1934	143	10	1,304	-	-	$ 1,817
1935	955	52	8,178	51,205	9,825	12,322
1936	411	-	25	22,761	-	5,710
1937	1,575	92	13,766	85,628	-	24,229
1938	415	16	2,707	23,306	-	4,594
1939	354	17	2,341	17,115	8,617	4,369
1940	26	3	443	3,230	-	785
1941	-	-	-	-	-	-
1942	19	1	69	700	-	169
1943	206	11	1,305	11,800	6,800	3,357
1944	212	6	1,004	8,000	-	2,004
1945	-	-	-	-	-	-
1946	-	-	-	-	-	-
1947	-	-	-	-	-	-
1948	50	1	439	2,800	1,480	1,305*
1949	-	-	-	-	-	-
1950	-	-	-	-	-	-
1951	-	-	-	-	-	-
1952	-	-	-	-	-	-
1953	-	-	-	-	-	-
1954	-	-	-	-	-	-
1955	-	-	-	-	-	-
1956	-	-	-	-	-	-
1957	300*	-	-	11,538**	-	3,000*
1958	600*	-	-	23,077**	-	6,000*
1959	250*	-	-	9,630**	-	2,500*
1960	-	-	-	-	-	-
	5,641	212	31,718	270,775**	26,722	72,381

Production of gold, silver, copper and lead in the Clinton mining district, 1934-1960. Years 1934-55 modified from Sahinen, 1957, p. 33.

*Approximation (Based on U. S. Bur. Mines Minerals Yearbook data).
**Equivalent copper (total metallic assay value converted to copper percentage)

TOPOGRAPHY

The Clinton mining district lies on the south slopes of the Garnet Range. Elevations vary from 3467 feet at the town of Clinton to 5444 feet at the Wallace Creek pass and 6365 feet at Kamas mountain, which is the most prominent topographic feature in the district.

The northwestern part of the Garnet Range is characterized by steep slopes dissected by narrow, V-shaped canyons having steep gradients. The upper slopes are more gentle, probably correlative with Pardee's mid-Tertiary erosion surface (Pardee, 1918, p. 163). Differential erosion of the less resistant Clinton stock has left a topographic low in otherwise relatively high ridges and mountains.

The area is drained by Wallace and Woodville creeks which converge and flow southwest into the Clark Fork River. These streams are perennial, but most of their tributaries are dry during the late summer and fall.

Near the confluence of Woodville and Wallace creeks is a small lake. Originally it was formed by a landslide which came from near the top of the ridge immediately to the south. At present the lake is impounded by a man-made earth dam. It is estimated from profiles of the slide scar that approximately 1.4 million cubic yards of material slid into the canyon. The slide scar and the slide are old enough to support timber of the same species and size as the surrounding country. The lake existed long enough to deposit a well-defined "flat" of sediments at its upper end.

CLIMATE AND VEGETATION

A semi-arid, temperate climate, typical of the Northern Rocky Mountains, prevails in the area. Weather conditions are roughly comparable to those at Missoula, for which the U. S. Weather Bureau has furnished the following figures. (Personal communication, 1961). Annual precipitation averages 16 inches and rarely exceeds 20. Temperatures vary from extremes of near -37° Farenheit in the winter to 103° Farenheit in the summer; the mean is 42°. Snowfall in normal years is heavy enough to impose transportation problems in the higher elevations during the late winter months.

The district is covered by coniferous trees and brush, except in lower valleys which have been cleared for farming and ranching. Trees in the wooded areas consist largely of fir and larch on the north slopes and ponderosa pine on the south. Most of the larger trees have been cut by logging operations. However, abundant trees of the right species and size for mine timbers are readily available on most of the mining claims.

GENERAL GEOLOGY

The Clinton mining district is located in a region of moderate structural deformation, characterized by northwest trending folds and faults and a northeast trending granodiorite stock.

The most important rock unit of the area is the small granodiorite stock which has intruded Proterozoic argillaceous quartzite of the Garnet Range formation and impure dolomitic limestone; according to Ross, et al.(1955) the limestone, which occurs north of the mapped area, is of Cambrian age. The effect of contact metamorphism is pronounced in the Garnet Range formation, where a dense hornfels can be seen as far as 600 feet from the contact. The limestone has been altered for distances up to 100 feet from the contact to a white crystalline marble containing typical contact minerals. A large diabase sill in the Garnet Range formation was cut by both the granodiorite and more recent rhyodacite porphyry dikes. Recent alluvium occurs along the principal stream valleys.

SEDIMENTARY ROCKS

Precambrian

Precambrian rocks are represented in the map area (Plate 6) by the Garnet Range formation and the overlying Pilcher quartzite. Both formations belong in the upper part of the Missoula group of the Belt series. In general, outcrops are scarce; logging and mine access roads provide the best exposures.

Garnet Range formation - Rocks of this formation are exposed west, south and east of the Clinton stock. The formation, which is quite consistent lithologically, is composed mainly of thin-bedded, greenish brown and gray quartzite with thin interbedded reddish argillite. It is best recognized by the large amount of detrital mica flakes it contains and the distinctive brown-weathered outcrops and talus slopes it forms. The thickness could not be determined in the thesis area. However, Montgomery (1958, p. 13) measured 5500 to 6000 feet exposed in the Nimrod area approximately 20 miles east. Nelson (1959, p. 55) measured thicknesses varying from 1800 feet to 3800 feet in the vicinity of Sheep Mountain approximately 15 miles west of the thesis area.

Pilcher quartzite - Rocks assigned to the Pilcher formation crop out along the south side of Wallace Creek where they are in fault contact with the Garnet Range formation. They consist mainly of reddish-orange, medium-grained quartzite, with interbedded yellow-green, arenaceous argillite. This lithology is characteristic of the upper parts of the formation (Nelson, 1959, p. 56). At least 300 feet are exposed in the thesis area.

Cambrian - Rocks of Cambrian age which occur north of the mapped area were observed during a geological reconnaissance. They appear to lie with slight unconformity on the Pilcher quartzite and consist mainly of flaggy, impure, dolomitic limestones. In weathered outcrop they are easily recognized by a light gray, chalky surface. They form a fine, reddish-brown soil upon decomposition. When freshly fractured, the rock is dark gray to black and is laced with small calcite-filled fractures.

Quaternary - Recent stream-deposited alluvium floors the Clark Fork River Valley and occurs along the lower reaches of Wallace Creek.

IGNEOUS ROCKS

Cretaceous (?)

Diabase sill - On both sides of the granodiorite stock, the sediments are intruded by a tholeiitic diabase sill between 300 and 900 feet thick. It was mapped from the southeast contact of the Clinton stock for a distance of over a mile into the Garnet Range formation. The Wallace Creek faults cut and displaced it into three segments. It appears to dip roughly 60° southwest as indicated by the dip of the enclosing sediments.

The Belt series rocks of northwestern Montana are intruded in a number of areas by diabase sills. In the Nimrod area directly to the east of the Clinton district, Montgomery (1958, p. 33) mapped a differentiated tholeiitic diabase sill which intruded the Garnet Range formation. From its similarity with other intrusions farther east which intrude the Colorado shale, and because it is partially covered by igneous flows of early and middle Tertiary age, he tentatively placed its time of injection as late Cretaceous. The relationship of the Wallace Creek sill to the other rocks in the area does not permit a closer age determination than post-Proterozoic and pre-intrusion of the granodiorite stock.

The texture of the sill is typically diabasic. It varies from medium fine-grained at the contacts to coarse-grained near the center. The rock consists essentially of plagioclase and pyroxene, which make up approximately 80 per cent of the constituents. Minor amphibole, calcite, magnetite and myrmekitic intergrowths make up the rest of the rock. Myrmekitic intergrowths are most common toward the top. Numerous lenses and bands of almost pure magnetite varying in thickness from one half inch to 8 inches were observed in the lower third of the sill. Abundant veinlets of carbonate cut the sill but seem to be most common in areas of fracturing. They are probably of hydrothermal origin.

The average modal composition of the rock is as follows:

Plagioclase	40%
Pyroxene	30%
Sericite	10%
Myrmekite	8%
Amphibole	7%
Iron ores	3%
Carbonate	2%

In thin sections the rock is extremely "dirty" as a result of strong sericitization. This sericitization may be alteration caused by intrusion of the Clinton stock. Seven thin sections were prepared from samples taken at irregular intervals across the sill where it is exposed along Wallace Creek. From this limited study, it is not possible to determine what effect the intrusion of the stock had upon the sill.

Late Cretaceous-Early Tertiary (?)

Clinton stock - The Clinton stock (common local name) is a small, hornblende granodiorite intrusion, one-half to one mile across and nearly five miles long in a northeasterly direction. It is exposed from the middle reaches of Wallace Creek on the south slopes of the Garnet Range to the main forks of Ashby Creek on the north, beyond the mapped area.

It is generally sheeted horizontally. The effect of weathering and erosion along the joint planes leaves cores of rounded boulders which crop out above the surface of the ground in a characteristic spheroidal weathering pattern. In the map area the contacts are discordant. The western and southern intrusive contacts appear to dip nearly vertically. However, the southeastern and eastern contacts dip approximately 65° beneath the overlying sediments and may connect with the Garnet stock farther to the east.

The granodiorite is inequigranular and coarse-grained, composed mainly of quartz, plagioclase, K-feldspar, hornblende, biotite and chlorite. Minor amounts of apatite and iron ores are also present. The composition and texture appear to be very uniform in the area mapped. No discernible change in grain size can be seen when comparing samples from near the contacts with those taken from well within the main body of the stock.

In hand specimens the rock is light greenish gray. Dark green hornblende occurs in abundant elongated crystals, sometimes as much as 20 mm long. Subhedral flakes of black biotite up to 4 mm across are present in small amounts. The light colored constituents, which make up about 80 per cent of the rock, consist of greenish plagioclase, faintly pink K-feldspar and milky colored quartz. Thin sections show that the plagioclase is the most abundant mineral, comprising approxi-50 per cent of the rock; it occurs in subhedral crystals, varying from 2 to 4 mm in length. Zoning of the plagioclase is common. Its composition, $Ab_{56}An_{44}$, places it in the range of andesine. Many of the crystals are extremely cloudy and others are almost unidentifiable, due to sericitization. Both Carlsbad and albite twinning are present.

K-feldspar (probably microcline) is present in amounts of approximately 15 per cent. It occurs in subhedral crystals, which average 4 mm and are sometimes as much as 12 mm long. Where not obliterated by sericitization, multiple twinning can be seen.

The hornblende prisms are generally euhedral. They vary in length up to 14 mm. Pleochroism is strong, varying from light brown to dark green. Partial replacement by biotite and later by chlorite is common. Some of the crystals have been broken and pieces whose broken ends can be matched are often found near each other. Hornblende comprises approximately 15 per cent of the rock. Quartz grains which make up 15 per cent of the rock fill the interstices between the earlier-formed minerals. Most quartz grains display undulatory extinction under crossed polarizing prisms. Biotite and chlorite plus minor apatite and iron ore make up the remaining 5 per cent of the rock.

Rhyodacite porphyry dikes - Numerous rhyodacite porphyry dikes occur in the district. They intrude all other rock units in the area and are, therefore, the youngest rocks present. However, all observations indicate that they were intruded before the time of vein deposition.

In outcrop they appear dark brownish-gray to light greenish-gray, with white euhedral phenocrysts of plagioclase up to 10 mm in length embedded in a gray groundmass. Small flakes of biotite and prisms of hornblende can be seen megascopically. Replacement of plagioclase by epidote is present to some extent in all exposures investigated. It is believed that the "epidotization" is related to hydrothermal activity for it is more prevalent in those dikes in which shearing can be observed. In some instances the replacement is so advanced that the entire exposure has a pronounced greenish hue.

Four thin sections of these rocks were studied. The coarse-grained fraction consists of andesine ($Ab_{56}An_{44}$), hornblende, biotite, chlorite, and sericite, which comprise approximately 50 per cent of the rock. Little can be said about the aphanitic groundmass because it is too fine-grained and has been too strongly sericitized for identification of the original minerals by optical methods. No quartz or K-feldspar could be observed in the groundmass; however, their presence was detected by X-ray analysis.

The andesine, which comprises about 60 per cent of the phaneritic portion, occurs as euhedral phenocrysts up to 10 mm in diameter. It is usually strongly sericitized and in some cases displays sutured edges that indicate it was partially resorbed by the melt before solidification. Zoning can be observed in some crystals. Most of the crystals poikilitically enclose numerous small hornblende euhedra.

The hornblende phenocrysts occur as elongated prisms up to 3 mm in length. They comprise approximately 30 per cent of the coarse-grained fraction. Biotite and chlorite make up approximately 5 per cent. They occur in small flakes from 0.5 to 1 mm across. Epidote, in radiating fibrous crystal clusters, is found partly replacing the plagioclase and makes up approximately 5 per cent of the rock.

No appreciable differences can be found in the mineralogy of the light or the dark colored porphyrys which in some cases crop out side by side. The difference in color may be attributable to a higher percentage of ferromagnesian minerals in the darker aphanite.

No chemical analyses are available for comparing the porphyry with the granodiorite but the phenocryst composition and X-ray evidence of quartz and K-feldspar in the groundmass suggests that the dikes and the stock originated from a common magma source.

In general, rocks of this type are found widely scattered throughout the district. However, they occur mainly in a well-defined zone one quarter mile wide located half a mile east of the granodiorite contact. Individual dikes vary in width from 4 to 50 feet. Maximum lengths of about half a mile were traced. All contacts observed in the field are knife-edged. No differences could be discerned in grain size near the edges of the dikes and no metamorphic effects could be found in the sediments.

The dikes in the zone strike roughly N 40° E and appear to dip nearly vertically. In other parts of the area the strike and dip of porphyry dikes varies somewhat at random. A small plug-shaped body of the rhyodacite intrudes the Garnet Range formation a short distance east of the Hidden Treasure portal. Two dikes extend from its northern contact.

It is believed that the dikes were emplaced along tensional fault fractures. Some dikes are sheared, indicating the effects of later faulting.

METAMORPHIC ROCKS AND CONTACT METAMORPHISM

The effects of contact metamorphism caused by the intrusion of the Clinton stock can be seen in a zone of hornfels 600 feet wide in the Garnet Range formation. This zone parallels the igneous contact, and, as might be expected, is most intense near it.

The rock appears light to dark gray with dark-colored spots, giving it a mottled effect. The mottling is caused by concentrations or clusters of very fine-grained ferromagnesian minerals and sericite. Differential weathering of the mottling produces protruding bumps of ferromagnesian mineral concentrations giving the rock a botryoidal appearance in weathered specimens.

Under the microscope, thin sections of the rock show that it is composed essentially of quartz and fine-grained dark green amphibole with scattered concentrations of fine-grained sericite. Small veinlets of chlorite fill fractures in some areas. Abundant fine-grained pyrite has formed locally along bands.

No contact effects were observed associated with the diabase or porphyry.

STRUCTURAL GEOLOGY

Folds - The Garnet Range formation in the map area is part of the south limb of a broad overturned anticline that extends eastward parallel to the grain of the regional structure. Pardee's map (1918, p. 172) indicates the crest to be located about one mile north of the mapped area, striking about N 50° W and plunging gently to the southeast.

Dips on the south limb are variable and are complicated by several northeasterly trending minor folds, apparently caused by forces attendant to the intrusion of the Clinton stock. Beds near the 4000-foot portal of the Hidden Treasure mine have been overturned slightly to the south.

Faults - Three inter-branching, east-trending faults with vertical movements estimated to be in the neighborhood of several hundred feet were mapped along Wallace Creek. The faults are steep-dipping. (See Plate 6). To the west, between two segments, a wedge of Pilcher quartzite has been relatively downdropped into the Garnet Range formation. To the east, a wedge of Garnet Range formation containing the diabase sill has been relatively downdropped. Although the faults are concealed, the following evidence indicates their presence and position:

1. The steeply-dipping Garnet Range formation is brought into contact with the relatively flat-lying Pilcher quartzite along Wallace Creek.
2. The diabase sill has been offset in two places.
3. Zones of brecciation and gouge can be seen in road cuts along their strike.
4. Wallace Creek and the West Fork of Cramer Creek form a lineament which can be seen on aerial photographs.
5. Numerous springs occur along the projected fault traces.

Several parallel lineaments which appear to be subsidiary faults can be seen on aerial photographs. They occur across a zone one quarter mile wide on the south side of Wallace Creek and extend for approximately 15 miles to the east along Wallace Creek and the West Fork of Cramer Creek. They are not shown on the accompanying geologic map. (Plate 6).

Two sets of mineralized minor faults can be seen on the surface and in the underground workings. One set strikes northeasterly and dips vertically to 70° east. The other strikes north-south and varies in dip from 70° to 25° west. These structures are considered in more detail under the heading Ore Deposits.

Two other non-mineralized faults which gave evidence of strong movement were observed in the workings of the Hidden Treasure mine. They strike roughly N 10° W and dip 80° W. At the time of the investigation, they were not sufficiently exposed to allow further observations; they are not exposed on the surface.

STRUCTURAL GEOLOGIC HISTORY

The structural geologic history of the Clinton mining district can be interpreted from the relationships of the igneous rocks and structural features in the mapped area. The first igneous activity resulted in the injection of a thick diabase sill in the Garnet Range formation. This event must have preceded regional folding because it seems improbable that the sill could have been injected concordantly in tightly folded rocks. Following injection of the sill, compressive forces acting in a northeast-southwest direction deformed the entire area during the Laramide orogeny in late Cretaceous or early Tertiary time. These stresses formed northwesterly trending folds and faults in western Montana.

To the north of the thesis area, the Garnet Range formation was folded into a northwesterly trending anticline. Igneous activity followed, resulting in the intrusion of the Clinton stock transverse to the regional structural grain. No definite age can be assigned to the stock, but based upon lithologic similarities, it is tentatively correlated to other intrusions in western Montana (late Cretaceous or early

Tertiary) from which age dates are available. Chapman, et al. (1955, p. 608), measured lead-alpha activity ratios in radioactive monazite and zircon from the Boulder batholith, and Philipsburg batholith. Based upon five samples, the average determination for the Boulder batholith was 68 million years, suggesting its time of emplacement at or near the end of Cretaceous. Based upon one sample, the age of the Philipsburg stock was found to be 50 million years or early Tertiary. Knopf (1950, p. 834-844), using Ar^{40}/K^{40} found an age of 78 million years for granodiorite from the Marysville stock at Marysville, Montana, suggesting emplacement in late Cretaceous.

Tension fractures post-dating intrusion of the Clinton stock were injected by magma, chemically similar, and probably genetically related to the granodiorite. This formed the rhyodacite dikes of the district. The chronology of the formation of the large normal faults along Wallace Creek is not entirely clear. However, it appears that it was pre-mineral because extensions of the veins are not found south of their traces along Wallace Creek. Later tensional fracturing provided openings along which the mineralized veins of the district were formed.

Subsequent warping and uplift, coupled with active erosion, have exposed the stock and the mineralized veins.

O R E   D E P O S I T S

GENERAL CHARACTER

The ore bodies of the district classified according to metal content and listed in order of economic value are copper, silver, lead, and gold deposits. The results of mineralization differ markedly in the sedimentary rocks (as seen in the Hidden Treasure mine) and in the granodiorite (as seen in the Cape Nome mine). These differences are probably attributable mainly to the differing chemical properties of the host rocks. There is also a distinct difference in the attitude of the main mineralized structures. In the sedimentary rocks, the major veins strike northeast, parallel to the igneous contact and dip from vertical to 70° southeast. In contrast, the veins within the granodiorite strike predominantly north-south and dip from vertical to 60° west. Most of the veins show evidence of pre- or post-ore fault movement by the presence of striations and fault gouge. It appears that the structures were formed in tension fractures caused by contraction of the igneous body during cooling.

Mineralization in the sediments occurs as small, discontinuous, lens-shaped replacement bodies in shear zones. These replacement bodies average 20 feet in length and are rarely wider than three feet. No well-defined ore shoots are known. A zone of ore mineralization in the Hidden Treasure mine appears to plunge steeply to the south, roughly parallel to the dip of the country rock.

In general, the mineralization in the veins within the granodiorite appears to be more continuous. The veins hold fissure fillings up to seven feet wide and continuous for distances of 200 feet. Because little active mining has been carried on in the granodiorite and most of the workings are inaccessible, relatively little is known of the details of the ore bodies there.

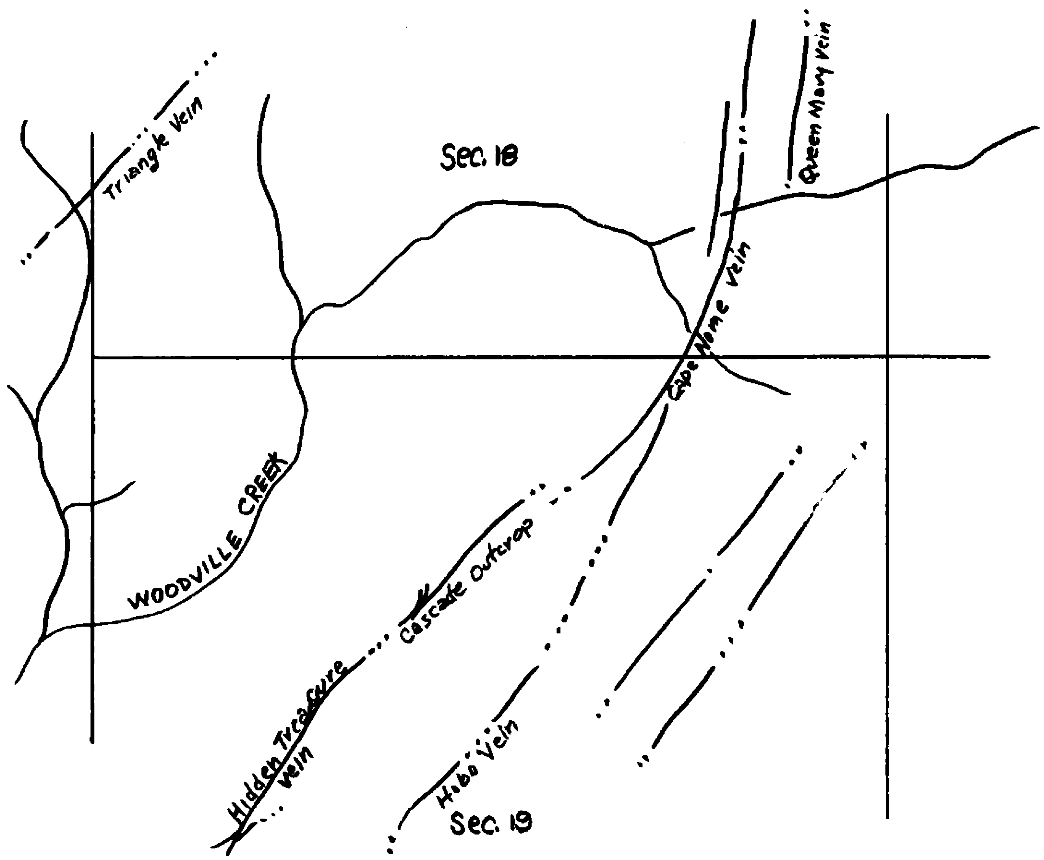


Figure 2 - Sketch map showing relative locations of veins in the Clinton mining district

MINERALOGY

Classification of Ore

Based upon mineralogy, five distinct types of ore can be recognized in the Clinton mining district. In general, they are developed dominantly in one or the other of the two vein types; replacement in the sediments and fissure filling in the granodiorite.

1. Chalcopyrite - tetrahedrite ore:

   This type occurs in the Hidden Treasure mine and is the most common association in the sedimentary rocks. The veins strike northeasterly and dip vertically to steeply east.

2. Galena - chalcopyrite ore:

   This ore is dominantly galena, but contains minor amounts of chalcopyrite and tetrahedrite. It occurs within the sedimentary rocks of the Hidden Treasure mine in stringers that strike northwesterly and dip relatively gently to the southwest. (See "flat faults" of Figure 5).

3. Galena - sphalerite ore:

   Only one occurrence of this type was noted, and it can hardly be called ore in a true sense. But it does represent a distinct type of occurrence. It is composed of almost equal amounts of galena and sphalerite with minor chalcopyrite, which occur in small stringers in a rhyodacite dike approximately 1200 feet east of the Hidden Treasure vein.

4. Chalcopyrite - bornite ore:

   This is the typical ore found in veins within the granodiorite.

In the Cape Nome vein it often contains appreciable amounts of enargite and chalcocite.

5. Oxidized ore:

This is essentially a weathered product of the veins of the district. It consists of weathered gangue and country rock with fractures and free surfaces containing the typical oxide minerals of copper and lead.

SULFIDE ORE MINERALS

Chalcopyrite - Copper pyrite ($CuFeS_2$) is the most common ore mineral in the district and was identified in all the veins investigated. It occurs in irregular stringers and veins up to 12 inches wide in the Hidden Treasure vein. Usually it is mixed intimately with gangue minerals and seldom occurs massively except in clot-like concentrations up to three inches in diameter. In the sediments it is associated with tetrahedrite and galena; in the granodiorite, with bornite and chalcocite. Chalcopyrite, in the Hidden Treasure mine, contains appreciable amounts of silver. Assays indicate that the ratio is approximately four ounces of silver for each per cent of copper; very little gold is present.

Tetrahedrite - "Gray copper" ($Cu_3(Sb,As)S_3$) is the second most abundant ore mineral in the chalcopyrite-tetrahedrite ores of the sediments. Its occurrence was not noted in any of the veins within the igneous rocks. In the Clinton district it is recognized by its gray color and reddish-brown streak. Apparently it carries very little silver for assay results show a ratio of about one ounce of silver for each per cent of copper present.

The tetrahedrite seldom occurs in massive concentrations, but rather as disseminations and fine veinlets. In some cases, where openings were available, it was deposited as small, perfectly-formed tetrahedra. The largest single crystal observed was approximately one-half inch across.

Galena - Lead sulfide (PbS) is widely distributed throughout the veins in the sedimentary rocks. It occurs only sparingly in the granodiorite. Its main occurrence is in the galena-chalcopyrite ores in narrow westerly dipping stringers in the Hidden Treasure mine. Finely crystalline "steel galena" when encountered in the more prominent veins quite often yields appreciable quantities of gold. Unfortunately, these occurrences are extremely small and infrequent. In the galena-sphalerite ores, it occurs as perfectly-formed cubes.

Bournonite - "Cog-wheel ore" ($PbCuSbS_3$) is found along galena-tetrahedrite borders.

Bornite - "Peacock copper" (Cu_5FeS_4) is found only in the chalcopyrite-bornite ores of the granodiorite. It is closely associated with chalcopyrite in the veins, and is usually accompanied by small amounts of chalcocite and enargite.

Enargite - var. Luzonite (Cu_3AsS_4) is found in most of the ore samples collected from the chalcopyrite-bornite ores of the Cape Nome mine. Megascopically, it is recognized by a dark gray sooty appearance and submetallic luster. In polished section, it has a definite pinkish cast.

Chalcocite - "Copper glance" (Cu_2S) occurs as a primary mineral in the hypogene zones of all the veins in the granodiorite. It is found as an important mineral constituent of the chalcopyrite-bornite ores in tł Cape Nome mine.

Pyrite - Iron sulfide (FeS_2) is found widely scattered in small amou throughout the district. But when comparing ore of the Clinton dist with other similar deposits, it is notably lacking in abundance. Nc mally it has a nearly white to pale yellow color. It occurs in minu fractured grains in the veins and in small striated cubes scattered throughout the wall rock.

Sphalerite - "Rosin jack" (ZnS) has been identified in the galena-ch pyrite ores in the Hidden Treasure mine; however, it is present in s small amounts that it hardly deserves mention. In the Hobo prospect east of the Hidden Treasure, sphalerite occurs in nearly equal amoun with galena. This occurrence is also unimportant from an economic standpoint because the deposit consists of a few small stringers, th largest of which are hardly one inch in width.

Covellite - Copper sulfide (CuS) has been identified in the hypogene ores of the Cape Nome mine. However, its occurrence is extremelv ra and its relationship to the other ore minerals could not be determin

SECONDARY ORE MINERALS

In general, the depth of oxidation extends from 100 to 150 fe below the surface. It is partial to complete to these depths. Wher fracturing has provided permeable pathways for downward moving, mete waters, localized oxidation has been observed as much as 800 feet be the surface. A weak zone of supergene sulfide enrichment is found at the bottom of the zone of oxidation in the Hidden Treasure mine; its vertical extent averages 50 feet.

Cerussite - Lead carbonate ($PbCO_3$) is found in minor quantities in the oxidized outcroppings of some of the lead bearing veins in the district. It exists as crusts on galena and as small brilliant white crystals in cavities.

Chrysocolla - Copper silicate ($CuSiO_3 2H_2O$) occurs in the oxidized ores of all the veins in the district. Normally it is characterized by a waxy green to blue-green color and forms crusts or scales in fractures and on free surfaces.

"Copper Pitch" - A brown to black impure copper silicate is found in fractures and free surfaces of the oxidized outcropping of the veins. It appears to be quite often mixed with variable amounts of iron and manganese oxides.

Covellite - Copper sulfide (CuS) occurs as a supergene sulfide mineral coating galena and chalcopyrite in the workings of the Hidden Treasure mine. Its occurrence is extremely rare.

Chalcocite - Sooty copper glance (Cu_2S) occurs in small quantities in the upper workings of the Hidden Treasure mine where it replaces chalcopyrite and tetrahedrite. It cannot be recognized megascopically except where it has been deposited along fractures as a thin steely-gray film on chalcopyrite.

Malachite - Green copper carbonate ($Cu_2CO_3(OH)_2$) is the most common of the secondary copper minerals in the district. It forms greenish stains or small crusts on the veins where they are exposed at the surface. Where openings are available, it forms as small clusters of radiating acicular crystals. Malachite can be found as far as 800 feet below the ground surface where fractures have provided water courses for meteoric waters.

Azurite - Blue copper carbonate ($Cu_2CO_3(OH)_2$) is found in scattered occurrences in the district. It is nearly always very near the surface, where it occurs as thin bluish films in fractures. In some cases, it has been deposited as tiny crystals in cavities.

Native Copper (Cu) was identified in gravity concentrates during an attempt at milling oxidized ore from the Cascade outcrop. Its occurrence is limited and unimportant from an economic standpoint.

Chalcanthite - Blue vitriol ($CuSO_4 \cdot 5H_2O$) is found locally as a thin coating on the walls of old workings in the Hidden Treasure mine.

GANGUE MINERALS

Quartz - (SiO_2) This mineral is widely distributed in the ore deposits of the Clinton district. It forms the principal filling of all of the veins. Its usual occurrence is as a gray to white, fine-grained type. Most of it can be recognized as belonging to one of the several stages during which the introduction of quartz took place in the veins. Some of it, however, appears to represent highly silicified inclusions of wall rock.

Barite - Heavy spar ($BaSO_4$) is an abundant gangue mineral in the Cape Nome vein and is present in lesser amounts in most of the other veins of the district. On the 300-foot level of the Cape Nome mine, an intergrowth of massive barite and siderite was observed filling the entire width of the vein, which is as much as seven feet wide in one place. It is milky white in color and often coarsely crystalline. No individual crystals were found.

Siderite - Iron carbonate ($FeCO_3$) is present in all the veins of the district and is especially abundant in the veins within the granodiorite. It occurs as a creamy white mineral when fresh, but in weathered outcroppings, its color is deep reddish-brown. Where openings were available, it was deposited in perfect cockscomb crystals as much as one-half inch across. Siderite was positively identified by X-ray diffraction.

Calcite - Calcium carbonate ($CaCO_3$) is present in small amounts in all of the veins studied. It occurs as a late stage mineral of hypogene origin. In the Hobo prospect east of the Hidden Treasure mine, it constitutes the principal gangue.

Hematite - Specularite (Fe_2O_3)was one of the first primary minerals formed. It is often found in thin seams so fine-grained and so nearly pure that it strongly resembled graphite. It occurs as clots and stringers and comprises one of the most common gangue minerals in the more prominent veins, although it was not observed in the galena-chalcopyrite ore veins. The Triangle and Alladin veins contain hematite so abundantly that they might more properly be referred to as deposits of iron rather than base metals.

HIDDEN TREASURE MINE

Development

The development work of the Hidden Treasure vein has been accomplished largely through adits, known as the No. 1 tunnel (at 4263 feet elevation) and the No. 2 tunnel (at 4000 feet elevation). The ore bodies have been stoped considerably above the upper tunnel, but are essentially unexplored between the two levels. About 1800 feet of drifts and crosscuts have been driven on the upper level, and about 2900 feet on the lower level. The two levels are interconnected by a vertical, two-compartment raise and a "doghole" raise which connects with the original discovery shaft. (Refer to vertical section shown on Plate 5).

Ore Bodies

The ore bodies in the Hidden Treasure mine occur along a northeasterly trending, steeply dipping shear zone, known as the Hidden Treasure vein. The attitude of the zone is irregular, but it averages N 40° E and dips from the vertical to 70° east. The width varies from three feet to 40 feet. Mineralization has taken place both as fissure filling and replacement of the country rock. Replacement is most common.

It appears from data collected during geologic mapping that significant mineralization occurs where splits from the predominantly eastward dipping fractures diverge locally to a westerly dip. Plates

1, 2 and 3 are geologic maps of portions of three levels of the Hidden Treasure mine. Note how the mineralization occurs in the westerly dipping splits. This divergence apparently caused some or all of the following conditions which were favorable for mineralization:

1. The intervening rock became brecciated and was more permeable for mineralizing solutions.
2. It is possible that the west-dipping splits were the main conduits for ore-forming solutions from depth.
3. More fault gouge appears to have been formed where the more radically divergent splits occur. This may have caused local impermeability to mineralizing solutions causing the metallic ions to be concentrated and precipitated.

The localization, size, shape and continuity of the ore bodies are directly attributable to the effects of multiple stages of faulting. Four distinct stages were recognized and mapped in the Hidden Treasure mine. Figures 3 through 6 are idealized cross-sections of the ore body in the 4001 raise, showing the inferred stages of development.

Scale 1 inch = 20 feet

Fig. 3

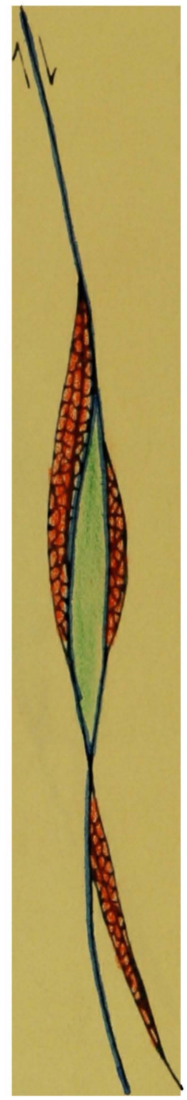
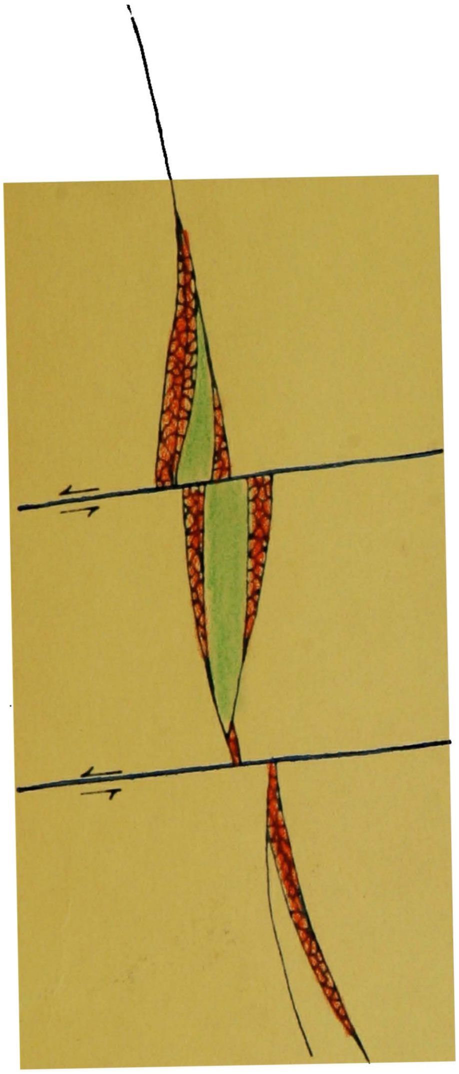
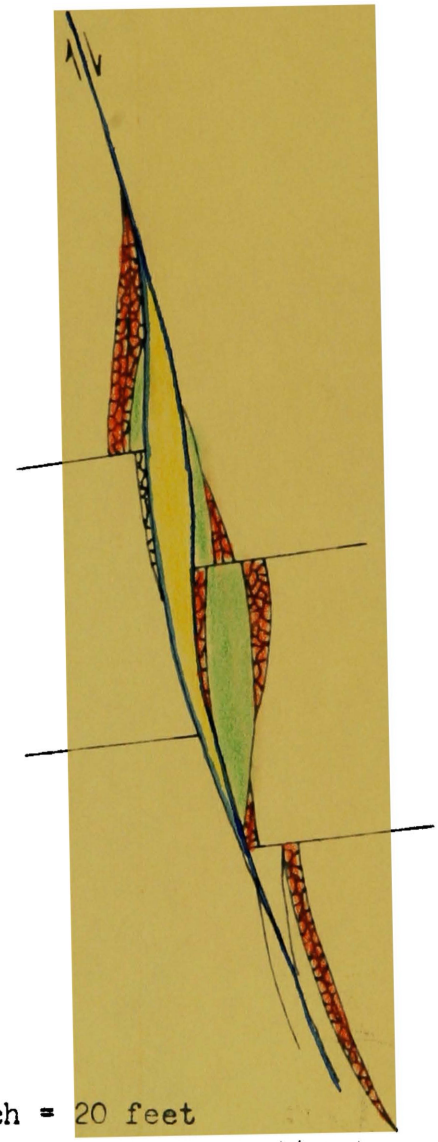


Fig. 4

Figures 3 and 4 are idealized cross sections of the vein in 4001 Raise of the Hidden Treasure mine looking northeast. Figure 3 shows initial faulting which produced movement along a curved fault plane. The opening was apparently partially filled with fault gouge and brecciated wall rock. Mineralizing solutions penetrated all available open spaces and cemented the crushed wall rock. The second stage of faulting shown in Figure 4 followed closely along the path of the first. Again a curved fault plane was formed which cut diagonally through the earlier formed vein, filling and displaced it into three segments. Ore mineralization was introduced along this fracture and replacement took place for short distances outward. Massive vein filling took place where openings were available.





Scale 1 inch = 20 feet

Fig. 5

Fig. 6

The third stage of faulting shown in Figure 5 formed what is locally known as flat faults due to their relatively flat dip which varies from 25 to 60 degrees to the west. (Apparent dip is shown in diagrams - dip is toward reader). In some cases these faults appear to follow along earlier formed joint planes. The displacement is to the west in the upper block. Displacements have been observed in the 4001 Raise of the Hidden Treasure which vary from a minimum of 3 inches to a maximum of 3 feet. It is believed that larger displacements do exist, but they probably do not exceed 10 feet. Post-mineral movement is evidenced by "gouge ore." The fourth stage of movement, shown in Figure 6, was along a path similar to that taken by previous near-vertical movements. Displacement was again along a curved fault plane which caused openings and received vein filling and wall rock replacement.

GEOLOGIC MAP OF A PORTION OF THE 4000 FOOT LEVEL (LOWER TUNNEL)

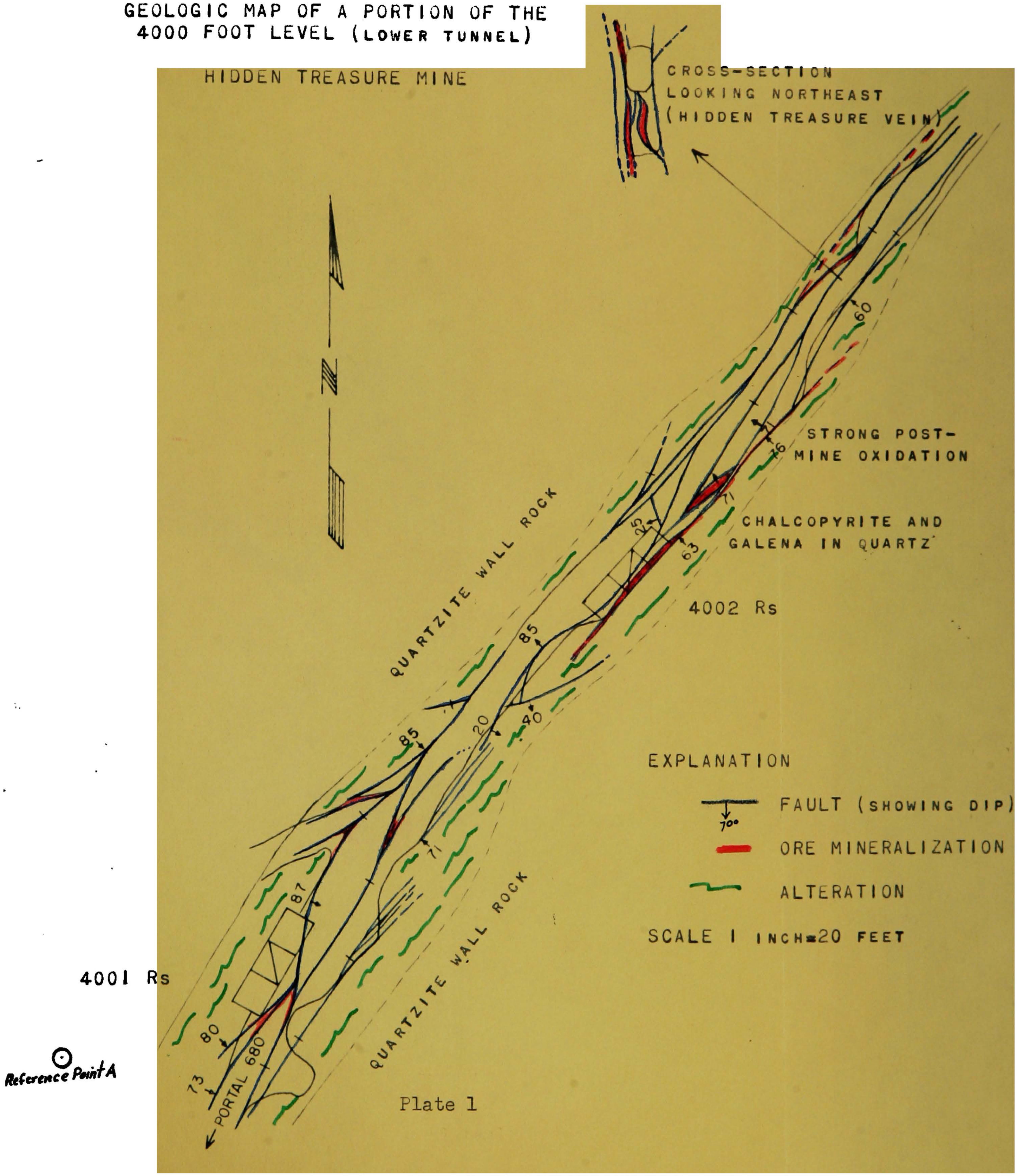


Plate 1

GEOLOGIC MAP OF THE 4100 FOOT LEVEL (4001) Rs, HIDDEN TREASURE MINE

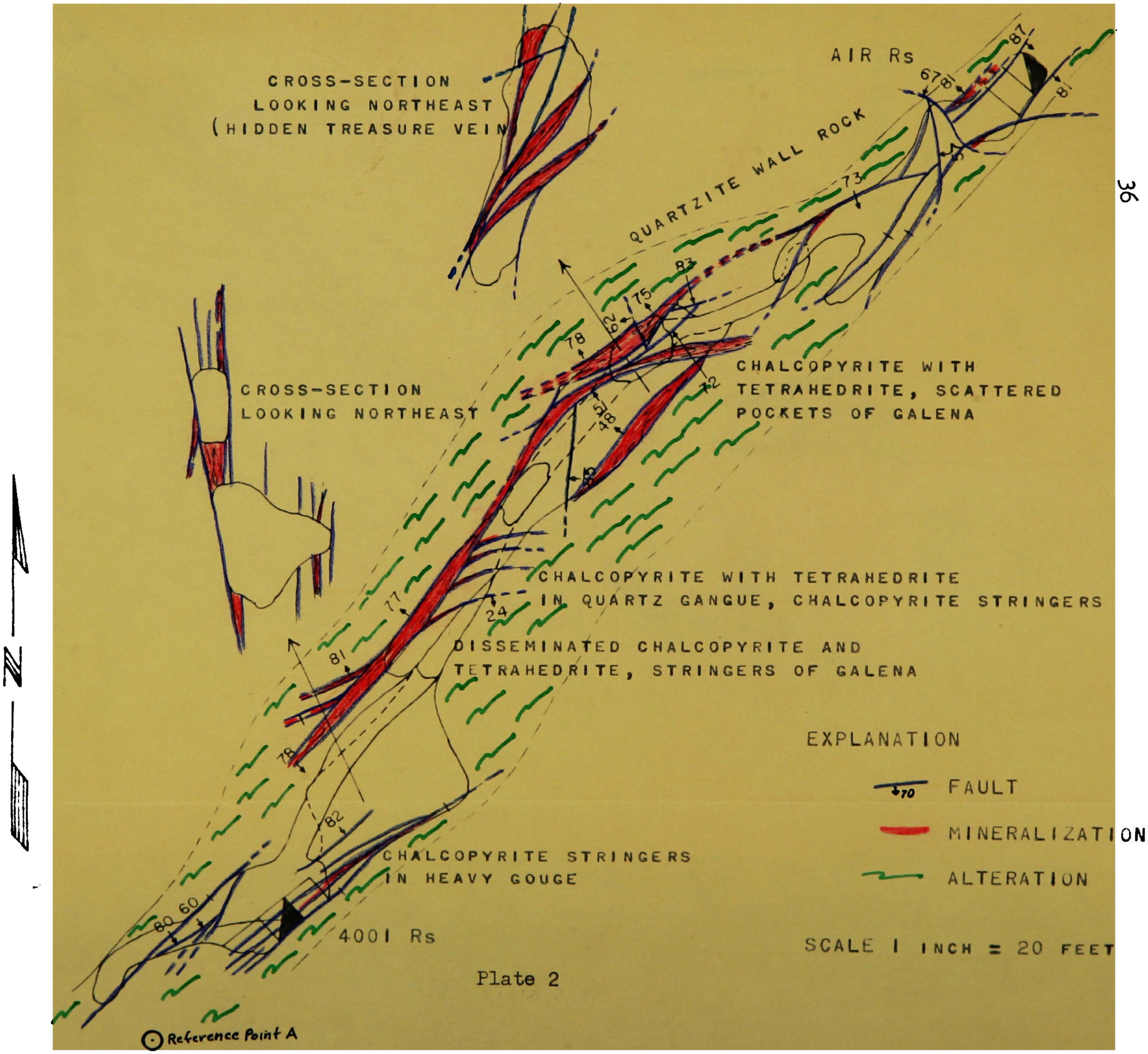


Plate 2

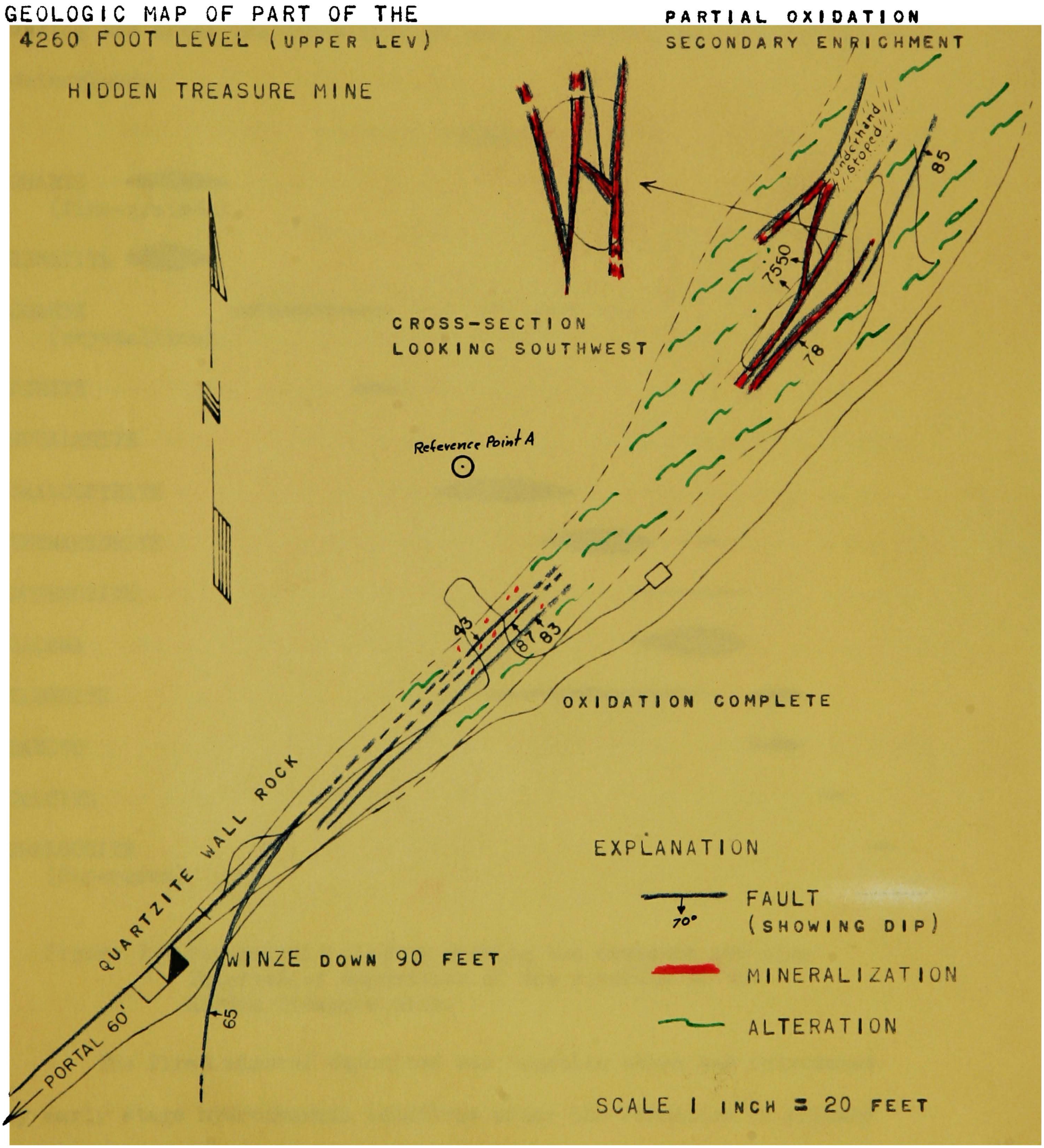

GEOLOGIC MAP OF PART OF THE
4260 FOOT LEVEL (UPPER LEV)
HIDDEN TREASURE MINE
PARTIAL OXIDATION
SECONDARY ENRICHMENT
Underhand Stoped
85
7550
78
CROSS-SECTION
LOOKING SOUTHWEST
N
Reference Point A
43
87
83
OXIDATION COMPLETE
QUARTZITE WALL ROCK
WINZE DOWN 90 FEET
PORTAL 60'
65
EXPLANATION
FAULT
70°
(SHOWING DIP)
MINERALIZATION
ALTERATION
SCALE 1 INCH = 20 FEET

Plate 3

Paragenesis

A microscopic study of polished ore samples revealed a definite sequence of deposition and gave an indication of the structural history during and after the deposition of ore. The following sequence was determined:

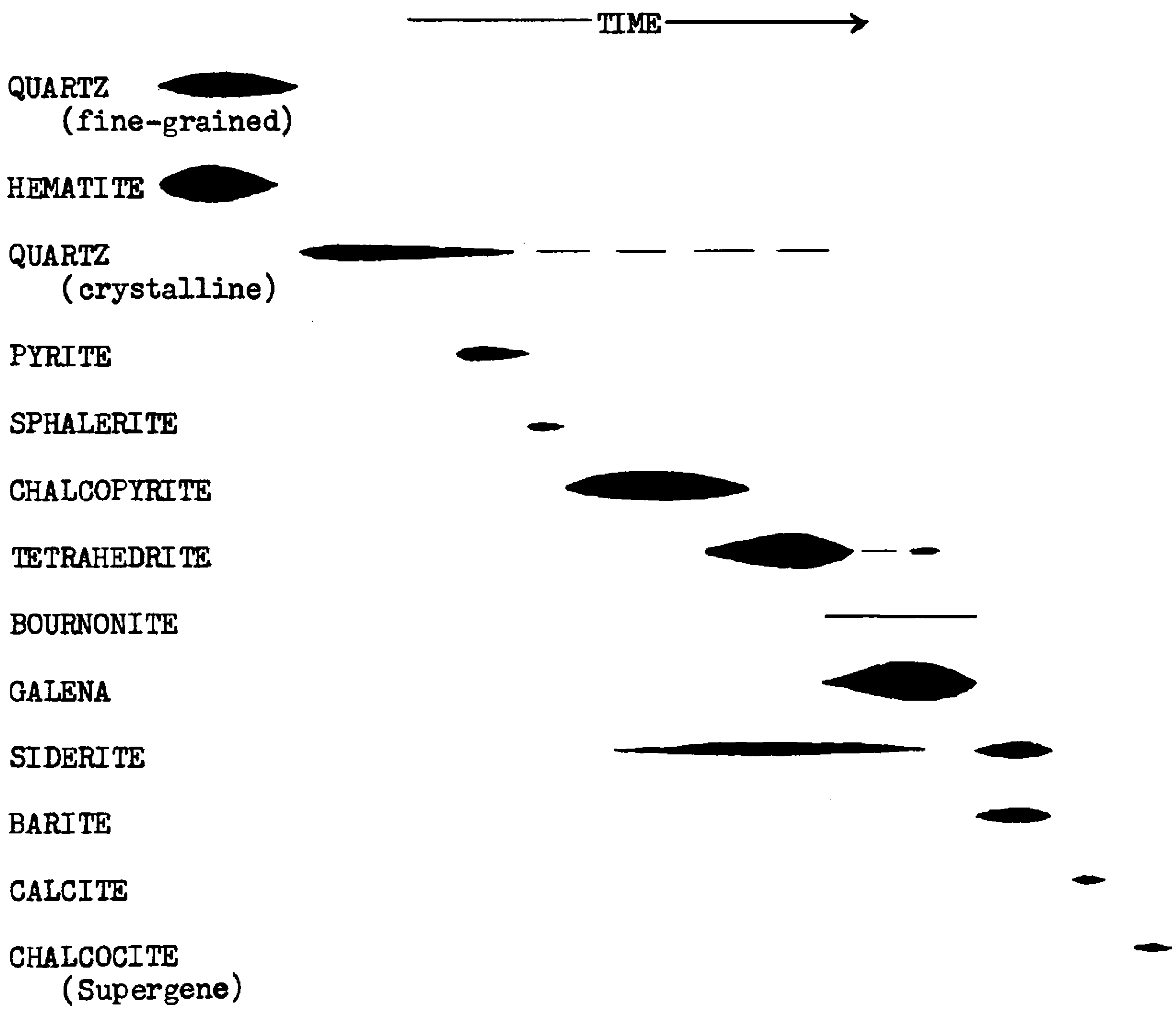


Figure 7 - Paragenetic diagram showing the sequence and time intervals of deposition of the minerals of the Hidden Treasure mine.

The first mineral deposited was hematite which was introduced by early stage hydrothermal solutions after the formation of primary fractures. This stage was accompanied by silicification of the wall rock and cementation of the zones of brecciation. (See Fig. 3). It appears that a limited amount of pyrite was also deposited at this time.

Subsequent movement brecciated the vein filling and reopened the fractures, making way for a new wave of solutions. Crystalling quartz and then pyrite were deposited along fractures in the wall rock and earlier vein filling. (Fig. 4). Sphalerite was deposited locally. There is no evidence of replacement during this stage of mineralization.

A change of conditions brought widespread deposition of copper in the form of chalcopyrite. (Fig. 8). It replaced quartz hematite and pyrite to some extent, and nearly obliterated any traces of the earlier formed sphalerite. Siderite deposition began in this stage and overlapped the next. Tetrahedrite followed and replaced hematite, chalcopyrite, pyrite, and locally, the wall rock for distances of up to six inches outward from the guiding conduit fractures. (See Figs. 9 and 11).

The next stage, in which galena was deposited (Fig. 10), appears to have been preceded by movement which widened the veins to allow fissure filling locally. Bournonite is found as a common mineral (probably resulting from the reaction of galena with tetrahedrite) along galena-tetrahedrite boundaries. Bournonite replaced tetrahedrite. Galena replaced all the earlier-formed ore minerals.

Repeated movement formed openings along which siderite and barite were introduced. Some replacement of the previous minerals by siderite can be found locally; however, both these minerals were deposited primarily as fracture filling.

Late stage tetrahedrite was deposited locally in vugs as perfect tetrahedrite crystals on siderite.

Post-mineral movements are evidenced by slickensided ore minerals and "drag ore" completely surrounded by fault gouge. Calcite can be found in small, late-formed fractures which cut the other minerals.

Secondary chalcocite was found to replace chalcopyrite and tetrahedrite in samples taken from the enriched zone above the 4260-foot level of the Hidden Treasure.

Figures 8 through 16 are photomicrographs of polished sections of ore samples from the Hidden Treasure mine, showing evidence for paragenetic relationships.

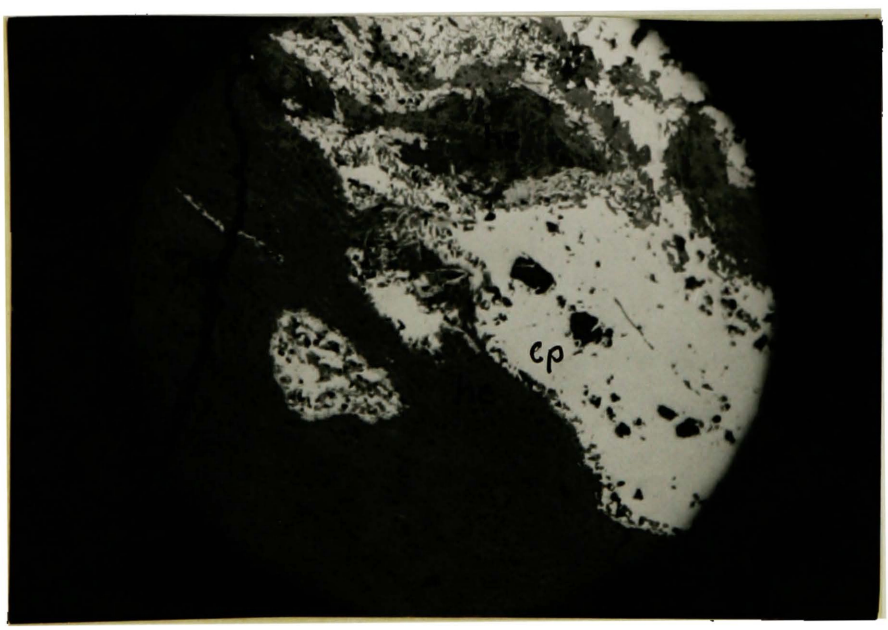


Figure 8 - Hematite (he) replaced and cut by chalcopyrite (cp). Notice that the chalcopyrite is not as badly pitted in this sample as in Figure 9. From the Hidden Treasure mine, 4001 Rs. x 55.

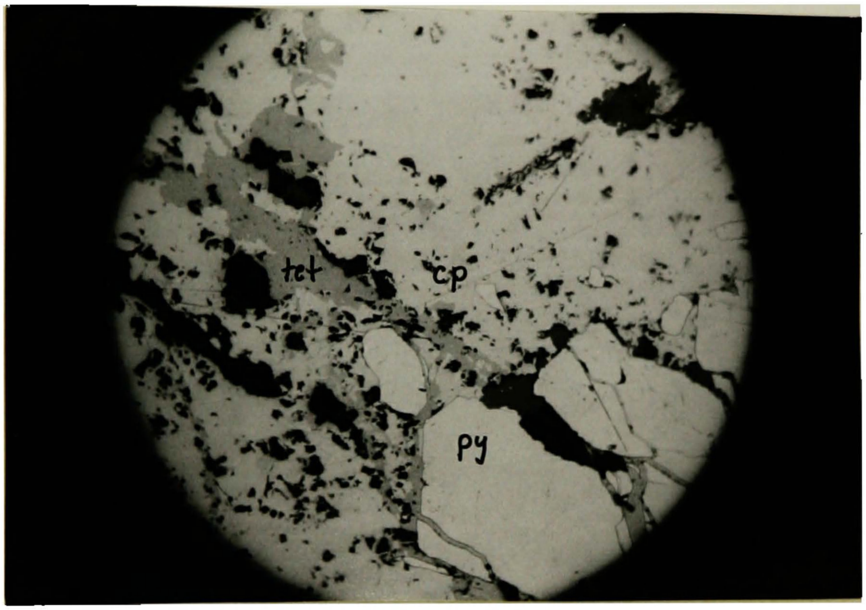


Figure 9 - Tetrahedrite veinlet (tet) cuts and replaces chalcopyrite (cp) and pyrite (py). A few small crystals of pyrite are enclosed in the chalcopyrite. Note their rounded outlines. Tetrahedrite appears to have preferentially replaced chalcopyrite over the pyrite. Note the pitted or corroded surface of the chalcopyrite. This may have been caused by corrosion by late-stage primary sulfate solutions. From the Hidden Treasure mine, 4001 Rs. x 55.

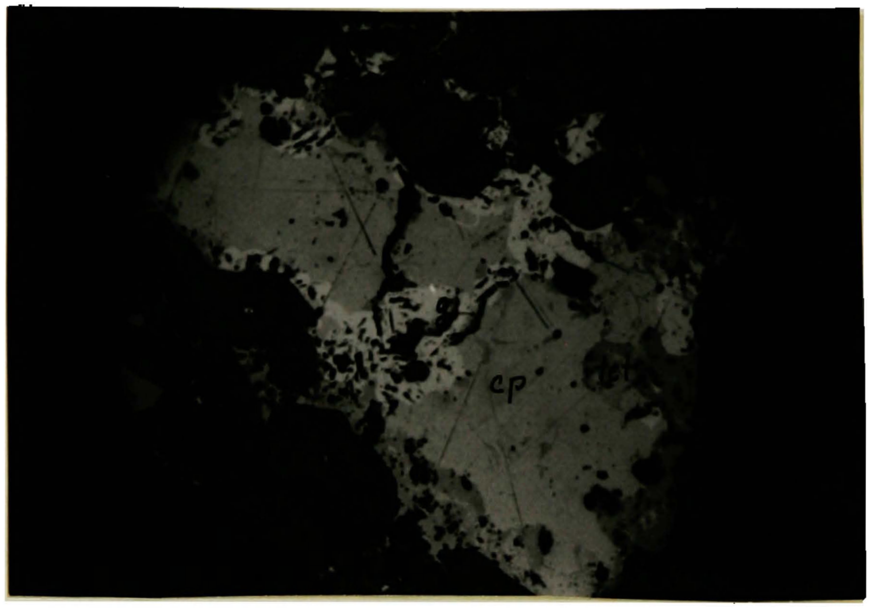


Figure 10 - Chalcopyrite (cp) has been replaced by tetrahedrite (tet). Both in turn were replaced by galena (g). Note how the pattern of replacement is controlled by the quartz contacts. The quartz crystals (q) enclose small blebs of galena and chalcopyrite. These may have been deposited on the quartz while crystal growth was still active early in the depositional sequence. From the Hidden Treasure mine, 4000-foot level. x 55.

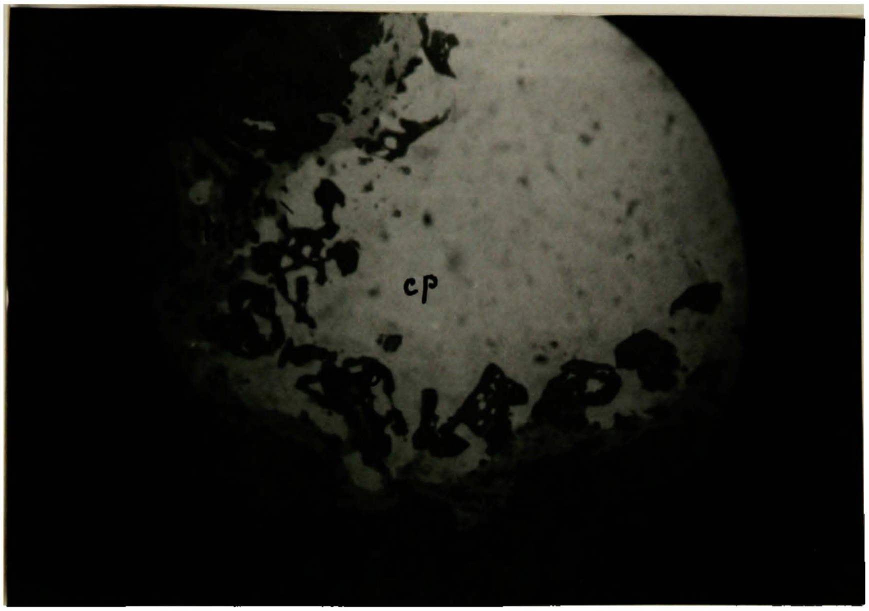


Figure 11 - Tetrahedrite (tet) has replaced hematite (he), chalcopyrite (cp) and siderite (carb) along mineral boundaries. Siderite and hematite were previously replaced by chalcopyrite. From the Hidden Treasure mine, 4001 Rs. x 55.

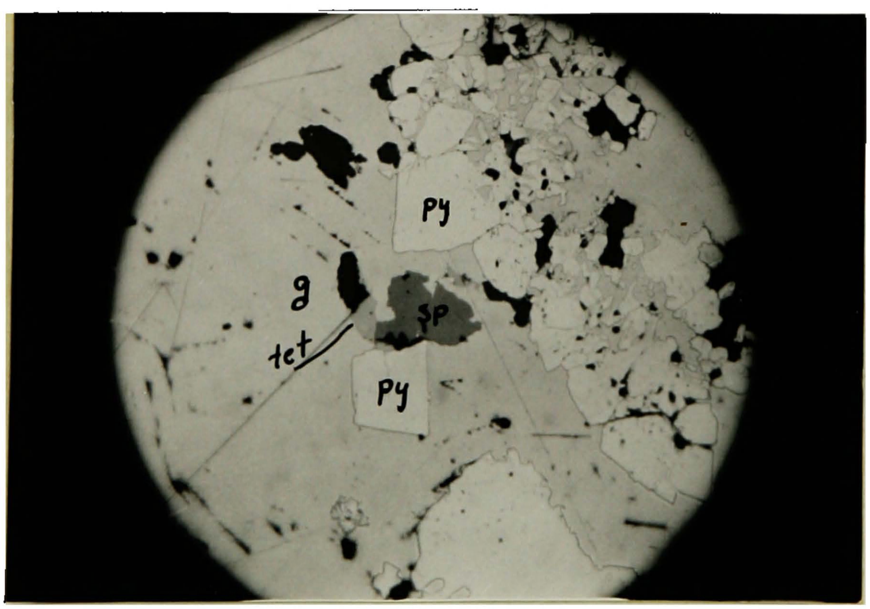


Figure 12 - Galena (g) has replaced sphalerite (sp), tetrahedrite (tet) and pyrite (py). Notice the corroded or sutured edges on the pyrite. From the Hidden Treasure mine, 4000-foot level. x 55.

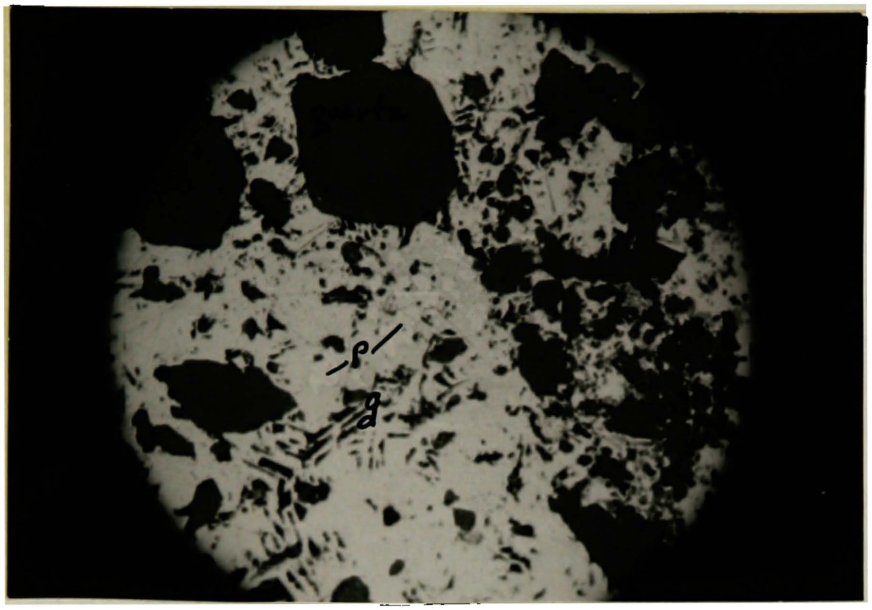


Figure 13 - Advanced replacement of pyrite (py) by galena (g). Quartz has been replaced to some extent. Note the rounded crystal outlines of pyrite. From the Hidden Treasure mine, 4001 Rs. x 55.

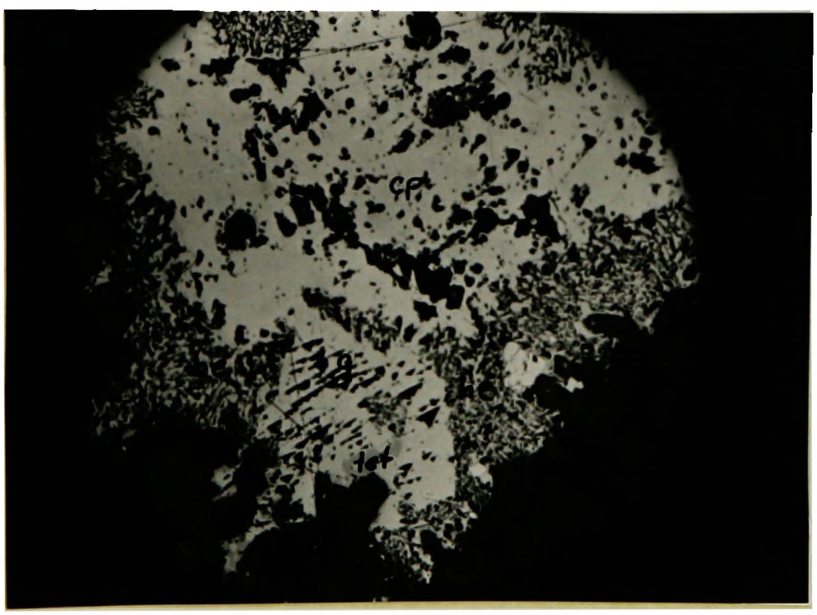


Figure 14 - Chalcopyrite (cp), tetrahedrite (tet), and galena (g) replacing hematite (he). Chalcopyrite in center was replaced by tetrahedrite, followed by galena, which replaced both. From the Hidden Treasure mine, 4000-foot level. x 55.

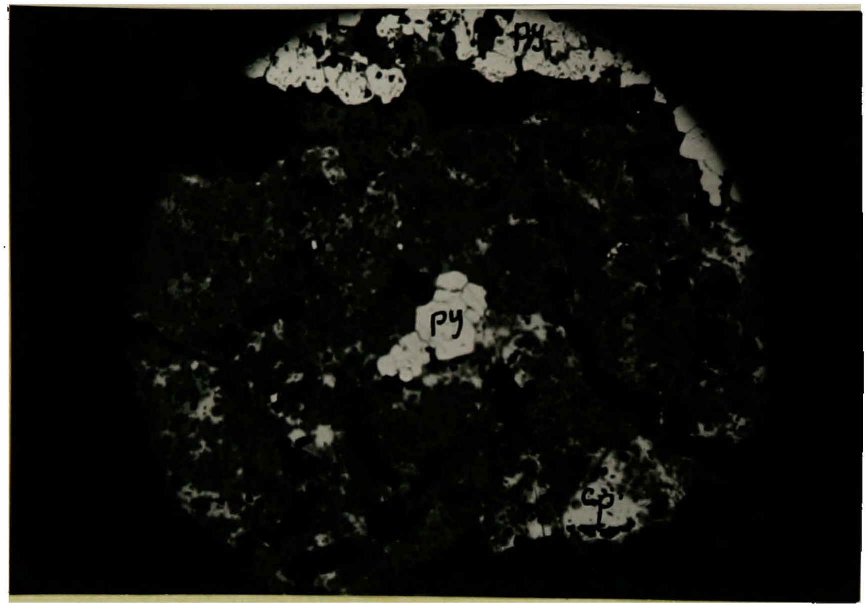


Figure 15 - Supergene chalcocite (cc) has replaced chalcopyrite (cp) and tetrahedrite (tet). Note the remains of pyrite (py) grains in the center and upper part of the picture. From the Hidden Treasure mine, 4260-foot level. x 28.

Figure 16 - Individual lath-shaped crystals of hematite (he) in chalcopyrite (cp). Carbonate (carb) of a late stage has preferentially replaced chalcopyrite and hematite along the hematite crystal boundaries. From the Hidden Treasure mine, 4001 Rs. x 310.

CAPE NOME MINE

Development

The development workings of the Cape Nome mine consist of two adits and a two-compartment, vertical shaft from which crosscuts and drifts have been driven on three levels. (Refer to the vertical longitudinal section on Plate 5, which shows the relationships of these workings). An aggregate total of nearly 6,000 feet of underground workings exist. They are described as follows:

1. Upper tunnel. This is an adit which was driven southward on the Cape Nome vein for approximately 800 feet. At the time of the investigation, it was caved and inaccessible.
2. Lower tunnel. (100-foot level shown on Plate 4, page 50). This is also an adit consisting of a crosscut for approximately 300 feet easterly to the Cape Nome vein and 350 feet of drift to the south. Another crosscut was driven westerly for 90 feet from the end of the drift.
3. Cape Nome shaft. A well-timbered, vertical, two-compartment shaft has been sunk to a depth of 500 feet. A sump extends 15 feet below this.
4. 200-foot level. A station was cut and a drift extended southward at a point 200 feet below the shaft color. It explores a weak structure not exposed in any of the other workings. There are approximately 75 feet of drift on this level.
5. 300-foot level. From the 300-foot level of the shaft, a

crosscut was driven easterly for 108 feet to the Cape Nome vein. From this point, a drift extends southerly along the vein for approximately 420 feet. The workings to this depth were examined briefly in 1958 during an attempt to dewater the Cape Nome shaft.

6. 500-foot level. The workings on the 500-foot level consist of a crosscut driven easterly for 124 feet to the Cape Nome vein. A drift along the vein extends for approximately 800 feet to the south. A raise on the vein connects the 300- and 500-foot levels from near the end of the crosscut. Rowe, (1910, p. 1101), reports that the Speculator Mining Company of Butte, Montana, extended a drift from the 500-foot level of the Cape Nome shaft approximately 1800 feet to the north.

Ore Bodies

The ore bodies of the Cape Nome mine occur along a series of northerly striking faults that dip from near vertical to approximately 60° west. The major structure in the mine is the Cape Nome vein, which has been explored for nearly 1000 feet along its strike and to a depth of 500 feet. Little is known of the vein on the 500-foot level, but according to old reports, it is "still strong and well-mineralized." During the course of this investigation, parts of the lower tunnel not covered by timbering were mapped in detail and the 200- and 300-foot levels were examined briefly.

The Cape Nome vein as seen in the lower tunnel (refer to Plate 4), dips nearly vertically and varies in width from five to 12 feet. Fissure filling is not continuous, but occurs in lens-shaped bodies 30 to 50 feet long and up to three feet wide. Oxidation of the vein in the lower tunnel has changed most of the primary sulfides (chalcopyrite, bornite, chalcocite, enargite, pyrite and galena), to secondary carbonates and oxides. Sulfides are present where the enclosing gangue has protected them from oxidation.

The crosscut of the lower tunnel also cuts another vein approximately 150 feet from the portal. Because the vein does not crop out at the surface, it is known as the Blind lead. It strikes nearly parallel to the Cape Nome vein but dips to the west at an average angle of 65°. It varies in width from 4 to 8 feet. Mineralization occurs as fissure fillings along the footwall in short lens-shaped bodies which appear to have greater vertical than horizontal dimensions. The greatest width of mineralization observed was slightly under three feet.

The ore minerals of the Cape Nome mine consist of chalcopyrite, bornite, chalcocite and enargite. Secondary malachite, azurite and sooty chalcocite coat fractures and free surfaces in vugs. The gangue is composed of quartz, siderite, and barite. Minor post-mine chalcanthite occurs locally.

During the brief examination of the Cape Nome vein on the 300-foot level in 1958, a reconnaissance was made through accessible workings, and samples were collected for laboratory study. Although no map was made and few measurements taken, the following brief description can be given: The vein varies in width from three to seven feet. Fissure filling by quartz, barite, siderite, hematite and copper sulfides appears in most instances to be continuous over this entire width. The vein dips nearly vertically near the shaft, but toward the southern extent of the accessible workings, it dips approximately 70° west.

The wall rock on this level is much "tighter" than on the upper levels and evidence of hydrothermal alteration even in close proximity to the vein cannot be seen megascopically. The ore minerals occur in disseminated blebs and narrow stringers. No massive sulfides were observed. Partial oxidation of the sulfides was found locally.

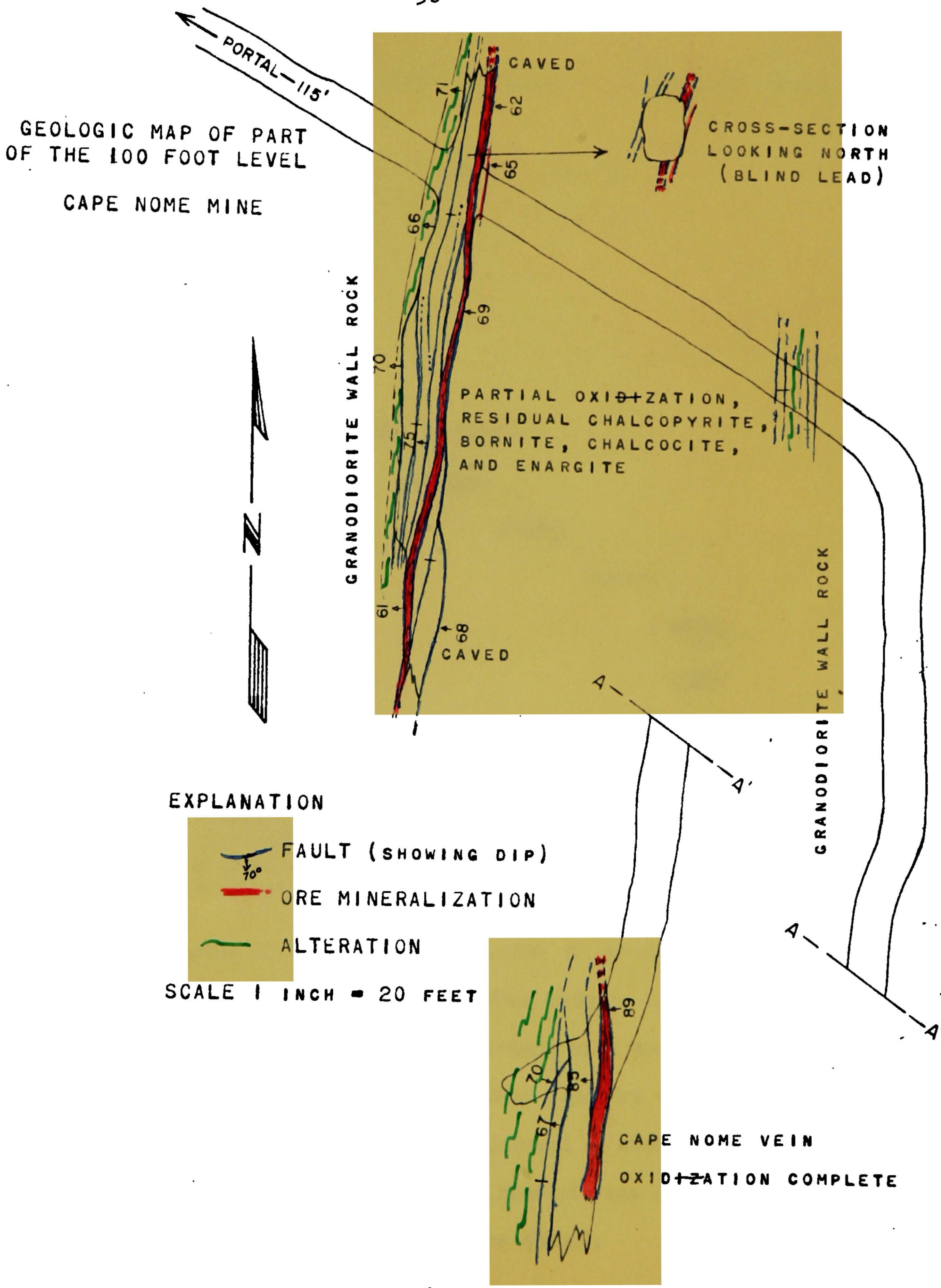

GEOLOGIC MAP OF PART
OF THE 100 FOOT LEVEL
CAPE NOME MINE
PORTAL—115'
CAVED
CROSS-SECTION
LOOKING NORTH
(BLIND LEAD)
71
62
65
66
69
70
75
61
68
CAVED
GRANODIORITE WALL ROCK
PARTIAL OXIDIZATION,
RESIDUAL CHALCOPYRITE,
BORNITE, CHALCOCITE,
AND ENARGITE
N
A—A'
GRANODIORITE WALL ROCK
EXPLANATION
70°
FAULT (SHOWING DIP)
ORE MINERALIZATION
ALTERATION
SCALE 1 INCH = 20 FEET
68
70
63
67
CAPE NOME VEIN
OXIDIZATION COMPLETE
A—A'

Plate 4

Paragenesis

The following is a paragenetic diagram of the minerals of the Cape Nome mine:

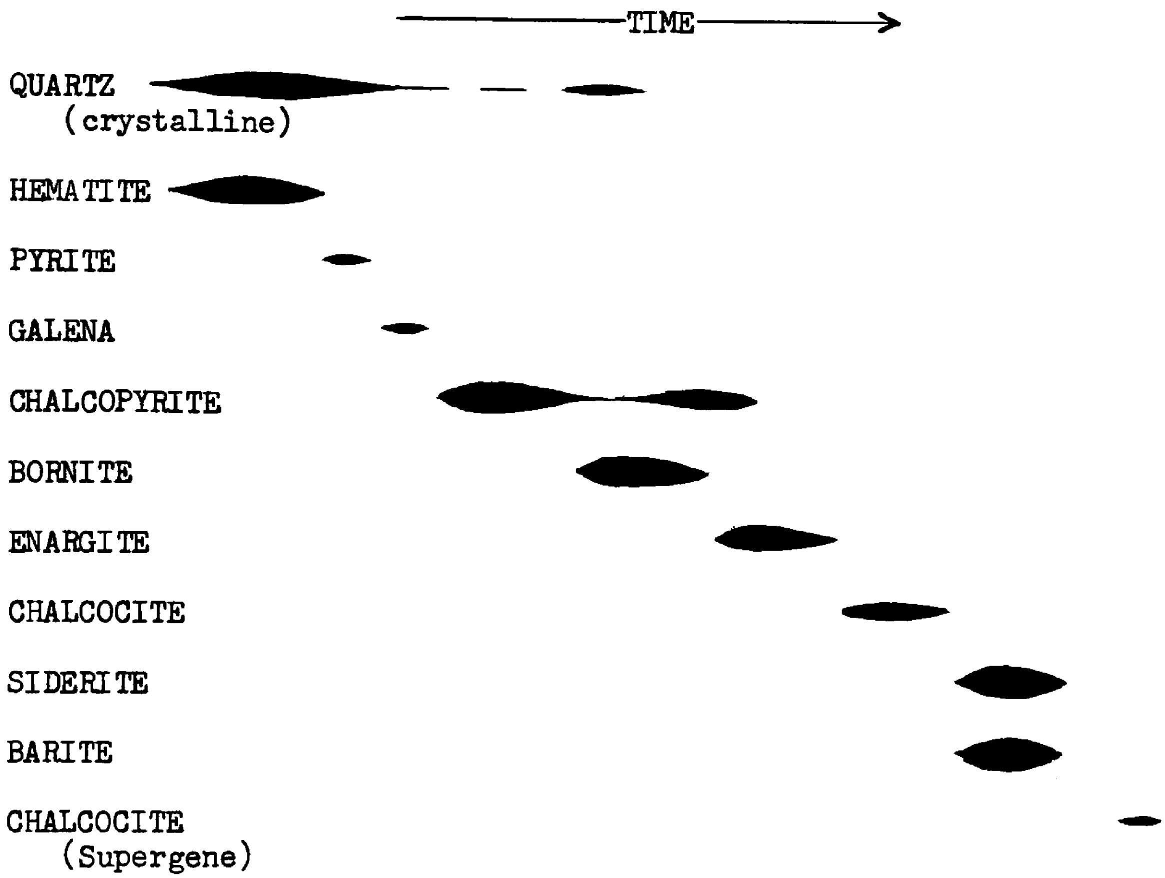


Figure 17 - Paragenetic diagram showing the sequence and time intervals of deposition of the minerals of the Cape Nome mine, based on samples from all the accessible workings.

The sequence of deposition of the ores of the Cape Nome mine begins with the introduction of silica along primary fractures in the granodiorite. This stage appears to correlate with the crystalline quartz stage of mineralization in the Hidden Treasure vein. Considerable open space for crystal growth is evidenced by abundant euhedral quartz crystals of this stage. Abundant hematite was followed by limited pyrite and was introduced with the quartz.

Movement which resulted in slight widening of the fissures was followed by local deposition of galena, then by copper-bearing solutions which deposited chalcopyrite. Bornite followed and replaced chalcopyrite (Figure 18). Either a renewal of conditions which precipitated chalcopyrite occurred, or there was an overlap. This stage was accompanied by slight fracturing. Chalcopyrite was deposited again in the fractures and replaced bornite in fine needle-shaped penetrations along cleavage planes. (Figure 20).

A change of conditions governing the precipitation of the sulfides was followed by deposition of enargite (var. luzonite). Enargite cut by chalcopyrite indicates that chalcopyrite deposition overlapped into this stage. Enargite cuts both the bornite and the chalcopyrite but appears to preferentially replace the bornite.

Mild fracturing was accompanied or followed by deposition of primary chalcocite. Veinlets cut all the previous minerals. Where they cut the boundary from chalcopyrite into bornite, they appear to swell slightly indicating a preference for replacement of the bornite.

Figure 22 shows chalcocite replacing bornite with a graphic texture.

Reopening of the veins was followed by widespread introduction of siderite and barite. Where open spaces were available, the siderite forms cockscomb-shaped crystal clusters. In most cases, the siderite and the barite were deposited separately, but occasionally they are found intimately intergrown, forming an interlocking texture. The siderite is also found replacing all the ore minerals. It forms fine hairlike threads in the center of the chalcocite veinlets that were evidently reopened during a late stage of fracturing. Secondary copper minerals are found replacing all the sulfides along late formed fractures.

Figures 18 through 23 are photomicrographs of polished sections of ore minerals from the Cape Nome mine.

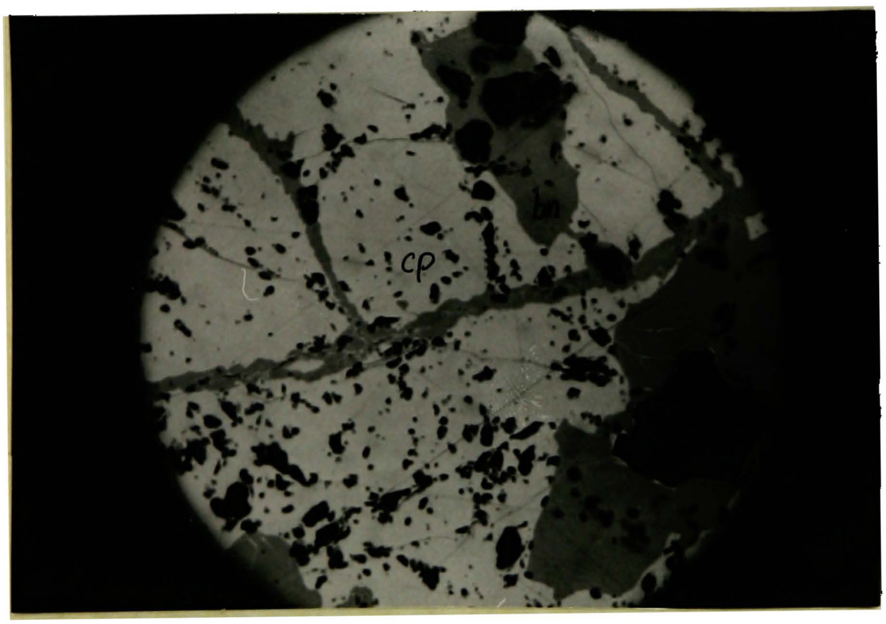


Figure 18 - Early stage chalcopyrite (cp) has been cut and replaced along veinlets of bornite (bn). The pitting in this sample was probably caused by late stage solutions which acted as strong solvents. Sample from the Cape Nome mine, lower tunnel, Blind lead. x 55.

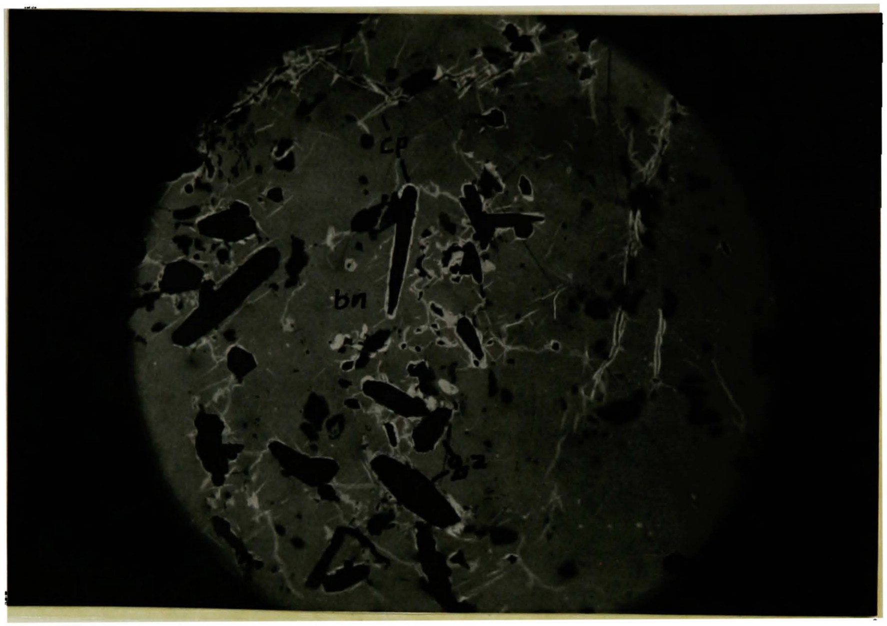


Figure 19 - Second stage chalcopyrite (cp) which has replaced bornite (bn). The replacement is guided along the boundaries of quartz (qz) crystals. The pitting seen in Fig. 17 is notably lacking in this sample. From Cape Nome vein, lower tunnel. x 55.

Figure 20 - Second stage chalcopyrite (cp) replacing bornite (bn) along bornite cleavage planes. The black spots are caused by pitting. From Cape Nome vein, lower tunnel. x 310.

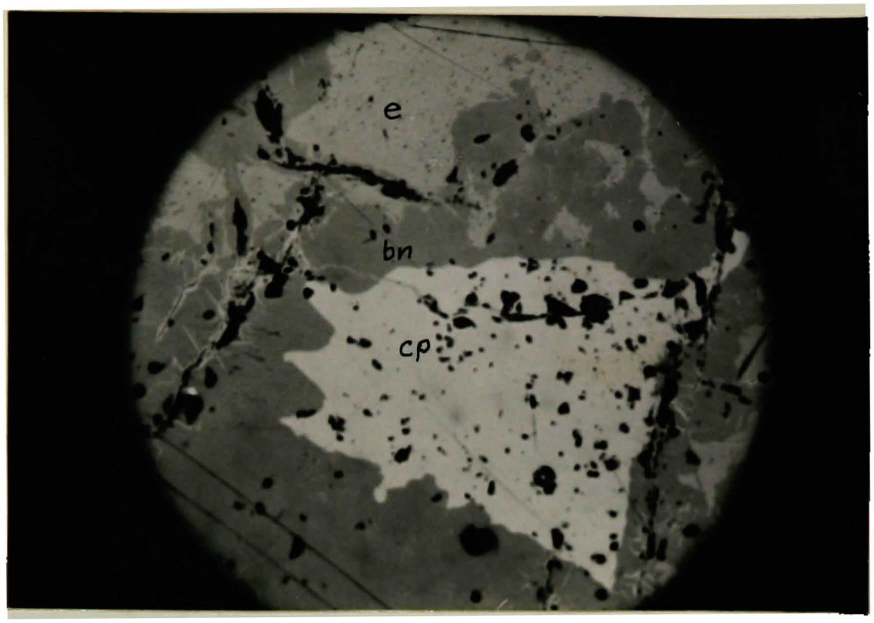


Figure 21 - Chalcopyrite (cp) and bornite (bn) show cusp and carie texture in this picture, indicating bornite has replaced chalcopyrite. Enargite (e) (luzonite) has cut and replaced both chalcopyrite and bornite. It apparently preferentially replaced the bornite. From Cape Nome vein, lower tunnel. x 55.

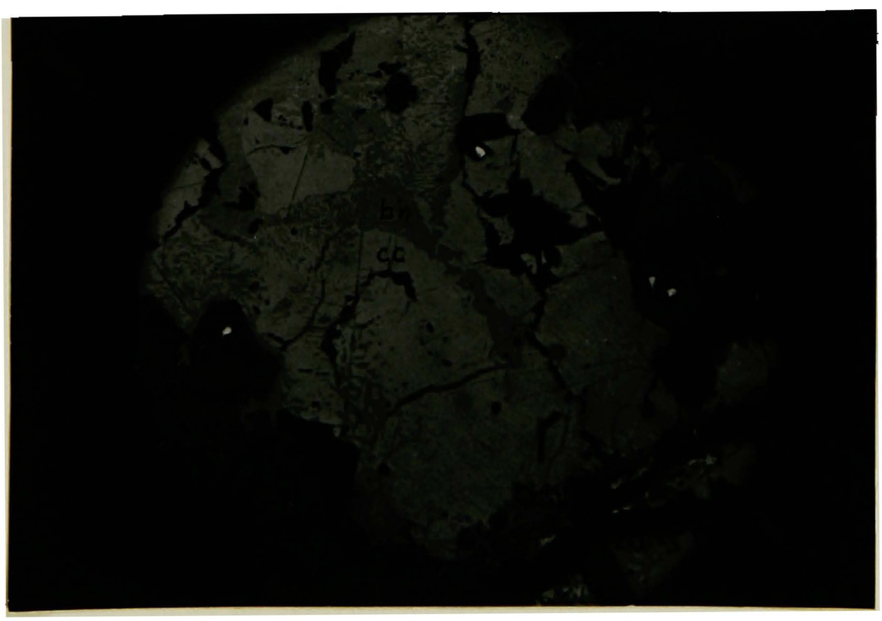


Figure 22 - Graphic intergrowth texture of bornite (bn) in chalcocite (cc) which has replaced it. The chalcocite is of hypogene origin. From Cape Nome vein, 300-foot level. x 55.

Figure 23 - Siderite (carb) has replaced all previously deposited ore minerals outward from a fracture. The fracture has been reopened by late movements. This was the only sample in which covellite (cov) was identified. Its relationship to the other minerals was not determined due to its isolated occurrence. The black line is an open fracture. From the Cape Nome vein, 300-foot level. x 55.

OTHER DEPOSITS

Surface exploratory work throughout the district has exposed a number of promising looking deposits, most of which are within the granodiorite. The individual veins seen on the surface are characterized by a central zone of iron discoloration and by bleaching, which extends outward on both sides. Discoloration is usually bounded by thick seams of clayey gouge probably formed by fault movement compounded by weathering, which caused the downward migration and concentration of hydrothermal alteration products of the wall rock. Most of the veins are from one to five feet in width; however, a few are as much as 12 feet. Measurements of surface exposures must be made with caution because "blooming" of the vein outcrops due to weathering is common.

Rowe (1910) described a number of other properties during a time when the district was active. The following descriptions are included to make a more complete treatment of the entire district in this report:

THE TRIANGLE GROUP - This group consists of eleven claims, the most important of which are the Triangle and the Grass Widow. There are two veins on the Triangle and the Grass Widow. These two claims are the ones mostly developed. The main vein has been drifted upon for 540 feet, with a depth from the outcrop, of about 400 feet. The vein or fractured zone is in the granite and has several stringers of high-grade copper ore running parallel with it. One of these stringers or seams assayed 15.4% copper, 0.24 oz. gold, and 3.2 oz. silver. It is claimed that the vein in the present face of the tunnel is 14 feet wide and samples taken from the face gave 2% copper, 5 oz. silver and 0.02 oz. gold.

The Grass Widow vein has been opened by two small drifts, one 50 feet and the other 75 feet long. While the writer did not visit the vein, it is claimed in the company's report that it is from 5 to 8 feet wide, thoroughly impregnated with chalcopyrite, azurite and malachite, and assays from these resulted as high as 26% copper, with gold and silver present. A crosscut from the Triangle tunnel 513 feet along to the Grass Widow vein has been run, and a drift of 170 feet run on the Grass Widow vein where this crosscut from the Triangle cuts it.

THE ALLADIN GROUP - This group lies directly north and east of the Cape Nome and has running through it the same vein as the Cape Nome ground. There are three claims in this group, the Alladin, Sovereign and "A" Ex.

Before 1907, the property was developed by a few prospect tunnels and shafts, but in 1907 the Speculator Mining Co. of Butte, Mont. took a lease and bond on the property and began to develop it from the 500-foot shaft level of the Cape Nome shaft. The company did 1700 to 1800 feet of drifting on a vein, crosscut to the west and a few feet to the east, but apparently did not strike the Cape Nome vein proper before time for taking up the bond expired and thence did not take over the property. The writer visited the underground workings on the Alladin ground at the time the company was operating, and believes that a crosscut to the east, not over 200 or 300 feet would cut the Cape Nome lead. It seems highly probable that when this lead is struck, good ore will be encountered. The surface indication and those in a shallow shaft, point to an ore shoot on the Cape Nome vein, as it continues in the Alladin territory. This, when cut by a crosscut from the main drift of the Speculator tunnel, would yield considerable stoping ground.

ALTERATION

Sericitization and silification are the dominant types of alteration found along the veins of the district.

Hidden Treasure Vein

In the sediments bordering the Hidden Treasure vein, alteration is recognized by strong bleaching of the wall rock. This is caused by sericitization and silicification of the metamorphosed Garnet Range formation. The intensity of the bleaching seems to be proportional to the intensity of mineralization and should be used as a guide in the search for ore. The halos of alteration extend outward from the veins for distances varying from one to 20 feet. Between the zones of alteration most of the rock is fresh, except where cut by subsidiary fractures. Alteration is most intense in the hanging walls of the veins.

Microscopic observations comparing fresh with hydrothermally altered material showed that the effects of alteration have caused removal of pyrite and amphibole and introductions of sericite and quartz.

Cape Nome Vein

In the granodiorite, alteration is weak in the footwalls, but the hanging walls are so intensely altered that heavy timbering is required to hold the ground during mining operations. In the upper levels of the Cape Nome, the alteration has softened the wall rock enough to increase permeability, thus allowing surface waters to penetrate and superimpose the effects of weathering on the hydrothermal alteration.

The intensity of alteration appears to be directly dependent upon the amount of dip of the veins. Where the dip is nearly vertical, no alteration halo can be seen megascopically. A thin section, however, showed some silicification, strong sericitization of the feldspars and chloritization of the biotite. Epidote, probably as a hydrothermal alteration product, has been deposited along joints and shear planes. As the dip decreases, alteration increases, especially in the hanging wall. This may be due to retardation of hydrothermal solutions along fractures of less dip, or to an increased amount of fracturing in the hanging wall which carried relatively greater amounts of hydrothermal solutions. Along the Blind lead in the lower tunnel of the Cape Nome, alteration is pronounced for distances of 12 feet into the hanging wall of the vein. The dip is approximately 65° to the west. Along the Cape Nome vein on this level, alteration is confined to a narrow zone approximately one foot wide on both sides of the vein. Here the dip is approximately vertical.

ENRICHMENT

When ore deposits, especially those of copper, are exposed to oxidization, sulphide minerals often break down into soluble and insoluble products. The soluble products are carried downward below the ground water table by meteoric waters and are frequently deposited as sulphides upon other sulphides, thereby forming a zone of supergene sulfide enrichment. In some districts this zone of enrichment is the only portion of the deposit rich enough to be mined.

One of the prime requirements for supergene enrichment is the availability of sulfuric acid and ferric sulfate, which take the metallic ions into solution. Most commonly, both solvents are derived from the decomposition of chalcopyrite and pyrite under weathering conditions.

Climatic conditions and the relative paucity of pyrite in the Clinton district may have hindered the adequate formation of solvents for strong supergene enrichment. However, weak supergene enrichment has occurred over a vertical distance of 20 to 100 feet below the ground surface. It was from this zone that most of the early production was obtained. It is possible that a long time of exposure to erosion together with an actively downward-moving water table has offset the relatively limited amount of available sources of solvents. While the supergene zone does not constitute a bonanza type deposit, it nevertheless is an important factor in the economics of the district for the ores are often twice as rich as those in the hypogene zone.

In general there is no enrichment of the oxide zone. However, local oxide "blooming" in some of the vein outcrops has caused appreciable apparent widening of the veins. Thus a narrow vein called the Cascade outcrop produced a substantial mining width at the surface.

MINERAL ZONING

What might be described as lateral zoning of minerals can be found when comparing the ores of the Hidden Treasure and Cape Nome mines. Whether this is caused by differences in the composition of the wall rock (which in turn affected the chemistry of the ore solutions), or differing pressure-temperature conditions during deposition, is not known. However, the former is suspected, mainly because of the fact that no bornite is found in the veins within the sedimentary rocks, but it is always found in adjacent veins in the granodiorite that must have been mineralized under similar temperature-pressure conditions. Also, galena which is abundant in the ores of the sediments, is present in very minor amounts in the granodiorite. Thus, it appears that there is a chemical rather than a temperature-pressure cause for the apparent mineral zoning.

E C O N O M I C   P O T E N T I A L

GENERAL CONSIDERATION

The fundamental factors to be kept in mind when considering the economic possibilities of a mining district are the available quantity and quality of ore and the profit that can be gained from its extraction. The profit depends upon prevailing metal prices and mining efficiency and is beyond the scope of this paper. Therefore, this discussion is confined to the size of the deposits, the depth to which they may be expected to continue, the metal content and the probability of discovering new ore.

SIZE OF THE DEPOSITS

Little can definitely be said about the size of the ore bodies of the district, except that those thus far developed have proved to be small.

The development and exploration work in the lower levels of the Hidden Treasure mine (to December 1960) has not indicated any ore bodies large enough or rich enough to be considered of any importance. Most of them are narrow, discontinuous lenses, which probably do not contain more than 200 tons of commercial ore. The exception may be in the relatively narrow zone of supergene sulfide enrichment. The outlines of the old workings in the Hidden Treasure mine indicate that minable ore bodies of perhaps several thousand tons were removed from this zone by early day mining operations.

The Cape Nome vein appears to have more continuity than any of the other veins investigated, but whether there is continuity of mineralization is not known.

DEPTH OF MINERALIZATION

The type of mineralization and the environment in which it occurs in the Clinton mining district suggest deposition under mesothermal conditions. The vertical range for deposits such as these is usually measured in several hundreds or thousands of feet. The development work on the veins is not yet sufficient to demonstrate the ultimate vertical range of mineralization in the district, but in the Hidden Treasure vein, the intensity of fracturing and primary mineralization appears to be consistent over a vertical range of at least 700 feet. Certainly the most promising prospect of developing ore bodies is in the zone of supergene sulfide enrichment. This zone is in the area between 20 and 100 feet below the ground surface. It has been largely ignored in the recent past because of attempts to develop paying production from the hypogene zone.

TENOR OF THE ORE

Several generalizations can be made in regard to the tenor of the ore as found in the different workings of the mines of the district. They are as follows:

1. The ore from the hypogene zone of the Hidden Treasure mine has averaged slightly less than two per cent equivalent copper. Assay results across the vein sometimes run as high as 10 per cent equivalent copper, but because of the nature

of the vein, it is necessary to mine barren waste rock along with the ore, thus causing dilution.

2. Ore mined from the supergene sulfide zone of the Hidden Treasure mine averaged nearly twice as rich as that from the hypogene zone. In some areas it was mined over widths of 10 feet.

3. Due to the differing mineralogy, the hypogene ore of the veins within the granodiorite is of a slightly higher grade than hypogene ore in the sediments. This ore can be mined with less dilution than that from the replacement bodies of the sediments because it is confined mainly to fissure filling.

SUGGESTIONS FOR PROSPECTING

It is believed that the success of future mining ventures in the district will depend to a great extent upon the scope of the operation. The district does not appear to be favorable for a large mining operation, but rather one that can efficiently exploit numerous small and scattered ore bodies with shallow workings. Efforts should be concentrated in the sediments near the granodiorite contact and within the stock itself, especially near its southeastern edge. Bulldozer trenching has proved to be one of the most efficient ways to determine the continuity of the veins on the surface. A small-diameter diamond drill should be used to confirm suspected ore bodies beneath the surface.

The supergene sulfide zone should be explored on all the known veins, especially in the Hidden Treasure and Cape Nome mines.

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